

JAMSTEC

2007 Annual Report



Japan Agency for Marine-Earth Science and Technology

Introduction

Under the belief of "knowing the earth through oceans," the Japan Agency for Marine-Earth Science and Technology aims to contribute to the sustainable development of humans through accumulation of scientific knowledge by making the most of the Agency's human resources, research facilities and other resources to cope with environmental changes on a global scale represented by global warming and large-scale natural disasters such as earthquakes with epicenters in oceanic areas.

At the end of FY 2007, the agency completed the fourth year since its inauguration on April 1, 2004. In the past four years, time flew literally. However, thanks to the warm support of the citizens of Japan, the Agency has been able to successfully proceed with its projects and compile an annual report on its activities conducted in FY 2007. I would like to take this opportunity to express our thanks for your support.

Looking back at FY 2007, one of the major topics was the commencement of international operation of the deep sea drilling vessel CHIKYU, which is our extensive project that took approximately 15 years from the concept to completion of the vessel. From now on, we will strive to operate the vessel as the main platform of the Integrated Ocean Drilling Program (IODP), in which a large number of countries including Japan, the United States and Europe participate, in order to report various achievements to the people of Japan. As a first step, we will continue to steadily work on a series of plans concerning the Nankai Trough off the Kii Peninsula, which will be the first scientific drilling, in the coming fiscal year and thereafter.

In addition, the Intergovernmental Panel on Climate Change (IPCC) won the Nobel Peace Prize. As an organization that has substantially contributed to IPCC's activities through efforts such as predictive research utilizing the Earth Simulator, it is a great honor also for us that IPCC, which has continually presented recommendations from a scientific viewpoint concerning climate changes including global warming, was recognized in such a way.

The Agency's contribution to IPCC has been made mainly through our research organization called Frontier Research Center for Global Change. The center celebrated its 10th anniversary in FY 2007. In addition, the oceanographic research vessel MIRAI and the deep sea research vessel KAIREI, which have supported the center's research activities in scientific observation, both celebrated the 10th anniversary of their services. These

organizations/facilities serve as the managerial base of the Agency and has supported the development of the Agency as a research institute. We intend to operate these organizations and facilities so that they can work more productively in the next decade.

FY 2007 was a year where oceans drew much attention also in terms of national policies. Specifically, the base for forcefully promoting ocean-related policies under an integrated structure has been built through the establishment of the Basic Act on Ocean Policy and the formulation of the Basic Plan on Ocean Policy in accordance with the act. The Basic Plan on Ocean Policy stipulates various policies including "Improvement of Scientific Knowledge of the Oceans." Our Agency is willing to contribute to the development of Japan, which is an oceanic nation, by actively participating in relevant policies.

Global issues such as those on oceans and global environment need to be perceived from an extensively cross-sectoral and integrated viewpoint, instead of being unilaterally viewed from one field of science and engineering. Under the motto of "unified comprehension of the life system on the earth," our Agency institutionalized a research structure based on a system science approach beyond the existing fields and methodologies in FY 2007. We will start specific research activities in the next fiscal year. In the first step, we will study the vicinities of deep-sea hydrothermal vents, which are said to be close to the environment of the primitive earth, and commence research for elucidating how life occurred and spread from the ocean while focusing on the geological environment and hydrothermal eruptions as well as the mutual relationship and action between microorganisms and the likes that depend on this environment. Our Agency intends to enhance research and development activities that are conducted from such a comprehensive viewpoint and that directly benefit society. We promise to live up to your expectations for those achievements.

As I mentioned in the beginning, our Agency was able to steadily accumulate achievements through the four fiscal years owing to your support. The coming fiscal year, FY 2008, is the final fiscal year of the current mid-term plan. In closing the introduction to the annual report FY 2007, I would like to convey that the Agency will press forward to make FY 2008 a year of great progress for the next mid-term plan based on the FY 2007 achievements described in this annual report.

Yasuhiro Kato

President, Japan Agency for Marine-Earth Science and Technology

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Chapter 1. Outline of Japan Agency for Marine-Earth Science and Technology

1. Activities

(1) Objective

The objective of the Independent Administrative Institution, Japan Agency for Marine-Earth Science and Technology (hereinafter referred to as "JAMSTEC") is to contribute to the development of academic ocean research as well as to elevate the level of ocean science and technology through comprehensive activities such as fundamental ocean research and development, and cooperative academic ocean research according to the philosophy of contribution to peace and welfare (Article 4, Law concerning the Independent Administrative Institution, Japan Agency for Marine-Earth Science and Technology [hereinafter referred to as the "Law"])

(2) Scope of activities (Article 17, Section 1, No. 1 to 7 of the Law)

- 1) To conduct fundamental ocean research and development.
- 2) To make the achievements of the above activity wellknown and promote their utilization.
- 3) To cooperate with universities and inter-university research institutes in academic ocean research through operation of vessels, etc.
- 4) To make the facilities and equipment of JAMSTEC available for use by those who conduct research and development or academic research in science and technology.
- 5) To train researchers and engineers in ocean science and technology and enhance their qualifications.
- 6) To collect, organize, store and provide internal and external information and materials on ocean science and technology.

2. Locations of offices and institutes

Headquarters	2-15, Natsushima-cho, Yokosuka-shi, Kanagawa, Japan Tel: +81-46-866-3811
Yokohama Institute for Earth Science	3173-25, Showa-Cho, Kanazawa-ku, Yokohama-shi, Kanagawa, Japan Tel: +81-45-778-3811
Mutsu Institute for Oceanography	690, Kitasekine, Sekine, Mutsu-shi, Aomori, Japan Tel: +81-175-25-3811
Kochi Institute for Core Sample Research	200 Otsu, Monobe, Nankoku-shi, Kochi, Japan Tel: +81-88-864-6705
Washington Office	1120 20th Street, NW, Suite-700, Washington, D.C. 20036, USA
Tokyo Office	Hibiya Central Bldg., 6F, Nishi-Shimbashi 1-2-9, Minato-ku, Tokyo, Japan Tel: +81-3-5157-3900
Global Oceanographic Data Center	224-3, Azatoyohara, Nago-shi, Okinawa, Japan Tel: +81-980-50-0111

3. Status of capital fund

Class	Total capital fund	Initial balance	Increase during the year	Decrease during the year
Government investment	84,210	0	0	84,210
Private investment	5	0	0	5
Closing balance	84,215	0	0	84,215

4. Executive officers

Title	Name	Time of office	Personal history
President (Full-time)	Yasuhiro Kato	April 1, 2004 - March 31, 2009	1967 Graduated from University of Tokyo, Faculty of Engineering 1995 Director-general of the Research and Development Bureau of the Science and Technology Agency 1999 Vice-Minister for Science and Technology
Executive Director (Full-time)	Kiyoshi Suehiro	April 1, 2006 - March 31, 2008	1980 Graduated from Doctoral Course, Department of Geophysics, Graduate School of Science, University of Tokyo 1996 Professor, Ocean Research Institute, University of Tokyo 1999 Japan Marine Science and Technology Center, Director of Deep Sea Research Department
	Tsutomu Imamura	April 1, 2006 - March 31, 2008	1971 Graduated from Graduate School of Engineering, Kyoto University 2001 Director-General, R&D Bureau, Ministry of Education, Culture, Sports, Science and Technology 2002 Director-General, National Institute of Science and Technology Policy
	Asahiko Taira	April 1, 2006 - March 31, 2008	1970 Graduated from School of Science, Tohoku University 1985 Professor, Ocean Research Institute, University of Tokyo 2002 Japan Marine Science and Technology Center,
Auditor (Full-time)	Mishihiro Kato	April 1, 2006 - March 31, 2008	1970 Graduated from Hiroshima University, Bachelor of Engineering 1995 Manager, Administration Division, Administration Department, JAMSTEC 2004 Director, Administration Department, JAMSTEC
Auditor (Part-time)	Yukiko Hori	April 1, 2006 - March 31, 2008	1963 Graduated from College of Social Relations, Rikkyo University 1974 President, Enoshima Aquarium Co., Ltd. 2001 Councilor, Japan Marine Science and Technology Center

- 7) To conduct operations ancillary to the above activities.

5. Staff

The authorized number of full-time staff at the end of FY 2007 was 328. The number of full-time staff decreased by 1 person from the end of the previous year, for a 0.3% decrease. The average age of the staff is 42.5 years (at end of previous year: 42.4 years). The full-time staff includes 17 persons loaned from the national government, etc. and 1 person loaned from the private sector.

6. Law constituting grounds for establishment

Law concerning the Independent Administrative Institution, Japan Agency for Marine- Earth Science and Technology (2003 Law No. 95)

7. Competent minister

Minister of Education, Culture, Sports, Science and Technology

8. History

- October 1971 At the request of the Japan Federation of Economic Organizations, Japan Marine Science and Technology Center was established as an authorized corporation with investments and contributions from government and industry.
- June 1990 The system of SHINKAI 6500 was completed.
- March 1995 KAIKO succeeded in the world's deepest dive in the Mariana Trench.
- October 1995 Mutsu Office was opened.
- September 2000 Washington Office was opened.

- September 2000 Mutsu Institute for Oceanography was inaugurated.
- April 2001 Seattle Office was opened.
- November 2001 Global Oceanographic Data Center (Nago-shi, Okinawa) was opened.
- April 2002 Earth Simulator recorded the world's highest computing performance.
- August 2002 Yokohama Institute for Earth Science was opened.
- April 2004 Independent Administrative Institution, Japan Agency for Marine-Earth Science and Technology was inaugurated.
- July 2004 JAMSTEC 2005 Annual Report Japan Agency for Marine-Earth Science and Technology was reorganized as four research centers and three centers.
- February 2005 Survey on the earthquake off the coast of Indonesia's Sumatra Island was implemented.
- February 2005 URASHIMA set a new world record with a continuous cruise of 317 km.
- July 2005 Deep-sea drilling vessel Chikyu was completed.
- October 2005 Kochi Institute for Core Sample Research was established.
- April 2006 The JAMSTEC venture support system was launched.
- August 2006 Drilling tests were conducted with the Chikyu.
- March 2007 Shinkai 6500 completed its 1000th dive.
- March 2007 Seattle Office was consolidated with the Washington, D.C. Office.
- September 2007 Start of exploration by the Chikyu in the Nankai Trough Seismogenic Zone Experiment (NanTroSEIZE), as part of the Integrated Ocean Drilling Program (IODP).

9. Introduction of offices and institutes

(1) Yokosuka Headquarters

JAMSTEC is engaged in research and development with the aim of elucidating global change phenomena, based on an understanding of the planet Earth as a single system centering on its oceans. As JAMSTEC's main research center, the Yokosuka Headquarters conducts advanced research and technical development on the global system, including research on prediction of global environmental change, research on the Earth's core dynamics, marine and extremobiosphere research, etc.

As infrastructure supporting basic research in these areas, the Yokosuka Headquarters owns various large-scale research facilities, beginning with research ships, and a dedicated quay, and conducts operation and management work to ensure that these facilities are utilized efficiently.

In addition, the Headquarters is also responsible for institute-wide management work such as personnel, accounting, administration, planning, compliance, and related matters.

(2) Yokohama Institute for Earth Sciences

The Yokohama Institute for Earth Sciences is a research center for the elucidation and prediction of global environmental change, research on the Earth's core dynamics, and similar topics, where simulations for these researches are developed with the full use of the Earth Simulator, the world's top-level supercomputer. The Earth Simulator is also used in research in

advanced scientific fields, etc.

In addition, as a data center of global environmental information, the Yokohama Institute for Earth Sciences has established a system for making the latest research results widely available to the public where various data obtained from research and observation activities are compiled and managed as electronic information.

The Center for Deep Earth Exploration, which is responsible for the operation of the deep-sea drilling vessel Chikyu, which began full-scale exploration in September 2007, also carries out its work at the Yokosuka Headquarters.

(3) Mutsu Institute for Oceanography

The Mutsu Institute for Oceanography (MIO, Photo 1) conducts time-series observational research in the North Pacific. It is the home port of the oceanographic research vessel Mirai, and provides support for observations by that vessel. The MIO also conducts various events and other activities aimed at increasing understanding of marine science and technology, centering on the Shimokita Peninsula region of Aomori Prefecture.

1 Time-series observational research in the North Pacific

The MIO is conducting time-series observation to capture environmental variations and changes in the ocean at Station K2(47°N, 160°E) in the subarctic northwestern Pacific Ocean. The "Mirai" made observational cruise MR07-05 was conducted in the autumn season in 2007, when the nutrients used by phytoplankton are at their lowest level. In addition, a buoy array was deployed with the aim of clarifying the detailed variations in nutrients at around a depth of 35m, and the seasonal and interannual changes in the composition of settling particles.

Observations carried out to date have revealed that the concentration of CO₂ on the surface layer in the subarctic gyre in the northwestern Pacific Ocean is increasing with time, and the composition of the particles from which organisms originate tends to change interannually. Furthermore, knowledge about seasonal variations in nutrients in the northwestern Pacific, the relationship between phytoplankton and primary production, seasonal variations in primary productivity, POC flux and others was accumulated based on disequilibrium of Th-234.

A compact drifting buoy in-situ automatic CO₂ measuring device (CO₂ sensor) was developed. This development is supported with the Marine Development and Earth Science and Technology Research Promotion Fund's "Japan Earth Observation System (EOS) Promotion Program (JEPP)". During FY 2007, a device made during FY 2006 was tested in

the ocean and improved.

(Details of these results are shown in "Institute of Observational Research for Global Change, Biochemical Cycles Group").

2 Support for Marine Observational Research

Support was provided for port entry/departure for four voyages by the R/V Mirai, maintenance of equipment such as the TRITON buoys and ARGO floats which are used in observations, processing of collected samples, etc.

A 10th Anniversary Project commemorating the commissioning was carried out because 10 years have now passed since the nuclear-powered vessel Mutsu was converted and R/V Mirai. The Mayor of Mutsu City was invited, and a special open house event at the Mirai was held during the general open-house at the MIO. Approximately 750 visitors participated in tours (Photos 2 and 3). In September, a 10th Anniversary Symposium of the Mirai was held for people who were involved in the construction of the Mirai in Mutsu City and the residents of the city. A total of 172 persons participated. (Photo 4).

3 Increasing understanding marine science and technology (public relations activities)

With the cooperation of the Mutsu FM radio station, FM Azure, the Mutsu Institute for Oceanography broadcasted newly and basic information to the region, mainly by researchers of the MIO, for 15 minutes each week in

order to deepen understanding of marine science, technology, and research. Various activities, such as lecture and openhouse to increase understanding of marine science, technology, and research and to introduce the Mutsu Institute were also carried out for the Shimokita region.

The seawater temperature was measured at Sekinehama, Noushi, Shimokita. The variations shown by the collected data were explained to persons related to the fishing industry around the Mutsu Institute through a Marine Environment Monitor Report Meeting (approximately 130 participants; Photo 5). Data were also presented in the magazine "UODAS" published by the Aomori Prefectural Fisheries Research Center.

With the cooperation of the Mutsu City Education Council, lessons about the environment of ocean at elementary and junior high schools in Mutsu City were continued from FY 2006. (Photo 6)

4 Symposiums and Open House Events

- Open house event at Mutsu Institute for Oceanography, including the R/V Mirai (July)
- 10th Anniversary Symposium of the R/V Mirai (September)
- Mutsu Marine and Environmental Science Symposium (November)
- Workshop on "Development of an Oceanic CO₂ Sensor and Observation using the sensor" (January)
- Special Lecture at Mutsu Fishermen's Association (February)
- Marine Environment Monitor Report Meeting (February)



Photo 1 Mutsu Institute for Oceanography



Photo 2 Tape-cutting ceremony for the start of the special open house for the R/V Mirai, held in conjunction with a general open-house at Mutsu Institute for Oceanography. From the right, Mayor Miyashita of Mutsu City, Kotaro Umenai (winner of the Mutsu Ocean Dream Picture Postcard Contest), and President Kato of JAMSTEC.



Photo 3 Some of the posters used in the 10th Anniversary Project of the R/V Mirai.



Photo 4 Scene from the 10th Anniversary Memorial Symposium of the Mirai (September 1, 2007).



Photo 5 Marine Environment Monitor Report Meeting (February 5, 2008)



Photo 6 Scene during a visiting lesson at Wakinosawa Elementary School in Mutsu City

5 Record of Media Presentations, Etc.

- FM radio program (weekly broadcasts)
- Introduction of technologies related to the Mutsu Institute by the Too-nippo Seeds Series (throughout the year)
- Results of time-series observational research in the North Pacific (April), “World’s First Successful Long-term, Automatic Sampling of Seawater - Expectations for an Elucidation of the Mechanism of Absorption of CO₂ by Seawater - ”
- Results of “Development of an Oceanic CO₂ Sensor” (June) “Start of Actual Ocean Testing of Compact Ocean Surface Layer CO₂ Partial Pressure Observation Device - A Large Advance toward to the Realization of Low-cost, Long-term Automatic Observation of the Distribution of CO₂ in the Surface Layer of Oceans - ”

6 Other Activities

- Visiting lessons at three elementary and middle schools in Wakinosawa/Kawauchi District in Mutsu City (November)
- Receiving of one middle school student for work experience (August)
- Receiving of three high school students for work experience (September)
- Marine environment monitoring measurements of Sekinehama and Noushi with the cooperation of Aomori Prefecture (throughout the year)

(4) Outline of Activities of Kochi Institute for Core Sample Research

1 Outline of Activities

On the start of international operation of the deep-sea drilling vessel Chikyu, the Kochi Institute for Core Sample Research was established in October 2005 as a research institute with combined responsibilities including operation of a refrigerated core repository for storage of core samples. As a result, it carries out activities as the nucleus research center for the series of processes in connection with analysis and research on core samples and safekeeping of the samples. At present, the Kochi Institute comprises three research groups, the Science Services Group, and the General Affairs Division.

2 Research Activities

(1) Physical Properties Research Group (Fault Research)

The Physical Properties Research Group is in engaged research with the aim of achieving a comprehensive understanding of earthquake faults based on material science, which includes promoting earthquake fault drilling science in the Nankai Trough Seismogenic Zone Experiment (NanTroSEIZE), Taiwan Chelungpu Fault Drilling Project (TCDP), etc., and measurements of various physical and mechanical properties and measurements of stress/strain, etc. of core samples containing fault rocks. In FY 2007, the group clarified the structures of anomalies and fault zones with high magnetic susceptibility and high water contents which occurred due to fault slippage in faults zones by analysis of drilling samples from the Taiwan Chelungpu Fault, and based on this, traced the mechanism of occurrence of high magnetic susceptibility in laboratory experiments and other research. The group also discovered that the principal stress direction in the vicinity of a fault zone changes by image analysis of core samples and the borehole wall, and thus succeeded in obtaining important evidence for designation of the fault which slipped in the 1999 Chi-chi Earthquake. These results were compiled and presented in more than 10 papers in international journals.

The Physical Properties Research Group is also actively participating in the Nankai Trough Seismogenic Zone Experiment which began in the autumn of 2007. The group has proposed various types of post-cruise research, and requested and received samples. At the end of FY 2007, the group began research using samples from the Nankai drilling. As shipboard research, researchers measured nonelastic strain using core samples from Nankai trough drilling, and were able to obtain secular change curves for strain having sufficient accuracy for stress analysis. The group also developed/introduced devices for simple, high accuracy measurement of various basic proper-

ties of the Nankai trough drilling samples, such as thermal conductivity, permeability coefficient, and the dynamic friction coefficient. Development and Introduction of an advanced high speed friction tester were completed, and ibasic preliminary tests were conducted, confirming that the device possesses satisfactory performance. The new device (photo) is capable of reproducing the water content, temperature, and pressure of faults in fault slip fields more realistically.

(2) Geochemical Research Group (Isotope Research)

The main objective of the Geochemical Research Group is to obtain a quantitative understanding of the movement/circulation processes of materials comprising the solid Earth's surface. With this objective, the group is engaged in the development of trace element/isotope analysis techniques for the carbonates, sediments, and rocks which make up core samples. During this fiscal year, the group established analytical routines for isotopes of lithium and strontium, and completed the development of the basic parts of a mass spectrometry technique and chemical separation technique for a magnesium isotope analysis method for carbonates. High accuracy analysis of trace amounts of lead contained in carbonates using the lead isotope analysis method established during the last fiscal year has become possible. The group is also developing applied research using these analysis methods. The strontium isotope stratigraphy of a core sample from the North Atlantic Porcupine Basin (IODP Epx.307) was determined, clarifying the growth process of a deep-sea coral mound. An analysis of the lead isotopes in sediments revealed that volcanic activity in a large igneous province with an age of 94 million years had a large effect on an oceanic anoxic event (OAE-2) from the same period. In joint research with the Physical Properties Research Group, the Geochemical Research Group is currently progressing with trace element/isotope geochemical research on fault rock core samples taken in the Taiwan Chelungpu Fault Drilling Project (TCDP). Research based on research voyages included achievements in understanding the genesis of the tectonic landforms which form methane hydrate, in study of methane hydrate in the Sea of Japan.

Methane hydrate is considered a promising energy resource for the future. However, it goes without saying that not only these exploration/development efforts, but also fundamental research to understand and evaluate how exploitation of this resource may impact material circulation and global environmental change from sub-seafloor to the surface layer will be necessary and indispensable. From this viewpoint, the Kochi Institute for Core Sample Research is conducting research on methane hydrate-bearing areas in off Naoetsu along eastern

margin of the Sea of Japan as joint research with the University of Tokyo, the National Institute of Advanced Industrial Science and Technology (AIST), and others. Studies to date have resulted in much new knowledge, including confirmation for the first time that methane hydrate is exposed on the sea bottom in the waters surrounding Japan, the discovery of hydrated methane gas bubbles, etc. Based on these results, the possibility that methane not only exists under the sea floor in the Sea of Japan, but may also reach the atmosphere, was suggested. The core samples which were taken are being stored at the Kochi Institute, and various physical properties are being measured using the Institute's multi-sensor core logger and other devices.

(3) Geomicrobiology Group (Subsurface Biosphere)

The quantity of microorganisms which exist in sea bottom sediments is generally put at 6×10^{30} cells, or approximately 60% of the total quantity of microbial cells on Earth. This is also thought to account for approximately 10% of all life, including animals. Many of the organisms that inhabit the sub-seafloor biosphere are life forms with unknown properties, which are completely different from the isolates which are known in phylogenetics, and knowledge of their metabolic functions and rates is extremely limited. In order to elucidate a complete image of this large, unknown biosphere, the Geomicrobiology Group is engaged in research taking advantage of techniques such as molecular biology and biogeochemistry, using core samples taken from the sea bottom and surface layer sediments.

During this fiscal year, in joint work with Bremen University, the Geomicrobiology Group extracted complete



Photo Fluid control-type medium-to-high speed friction tester capable of reproducing the water content, temperature, and pressure conditions of faults more realistically.

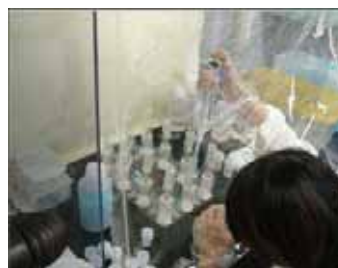


Photo Chemical separation of strontium from a deep-sea coral sample.

polar lipids and DNA from sediment samples from various parts of the world, including core samples to a depth of 365m below the sea bottom taken off Shimokita, Japan by the deep-sea drilling vessel Chikyu in 2006, and clarified the fact that many of the microbial living cells included in sea-bottom sediments are archaea (Lipp, Morono, Inagaki & Hinrichs, *Nature*, 2008).

Because archaea cells have a membrane structure with lower fluidity than bacteria, it is thought that they evolved by adapting to an environment with a low energy supply rate, that is, the environment provided by seafloor sediments.

In research on the sub-seafloor biosphere, accurate detection of the cells in core sediment samples and evaluation of their quantities is extremely basic and important knowledge. However, in visual observation by fluorescence microscopy, it is difficult to distinguish between the fluorescence emitted by the cells and that emitted by the sedimentary material, and the limit concentration for detection is high due to the limitations of identification by the human eye and the amount observed. Therefore, at the current point in time, it is not possible to carry out research exploring the limits of the sub-seafloor biosphere, targeting low biomass environments in future deep environments and high temperature environments. We developed a revolutionary new experimental system for accurately detecting and quantifying only living organisms (cells) containing DNA from the matrix of sedimentary materials by constructing a computerized automatic microscope control system and performing image analysis on the fluorescent spectrum of the fluorescence microscopy images obtained with that system (Morono, Terada, Masui & Inagaki, submitted to *Nature Methods*). Using the newly-developed technique and microscope system, the quantity of microbial cells contained in core samples of ODP Leg 201, which was the world's first subsurface biosphere drilling voyage, and cores taken off Shimokita were accurately evaluated based on objective digital data, reconfirming the existence of large quantities of microbial cells in deep sub-seafloor sediment samples.

Researchers from the Geomicrobiology Group also sailed on the Stage 1 expedition (IODP Epx. 315, 316) in the Nankai Trough Seismogenic Zone Experiment (NanTroSEIZE) and directly took core samples at multiple drilling locations, including a mega-splay fault and a fault zone at the leading edge (frontal thrust) of an accretionary prism. These samples are being stored in a cryogenic environment in a freezer or in an anaerobic refrigerator by this research group. Present work includes measurement of the biomass in Nankai trough drilling samples using the newly-developed automatic microscope system and analysis of the diversity of microorganisms using a

metagenomic technique, etc. in order to determine what kinds of linkage may exist between the distribution and functions of microorganisms in sub-seafloor environments and the distinctive features of organisms accompanying geological activity.

In the future, if the sub-seafloor biosphere is to be explored by large-depth drilling, evaluation of contamination in samples by external microorganisms accompanying riser drilling will be important. Taking advantage of the opportunity provided by the

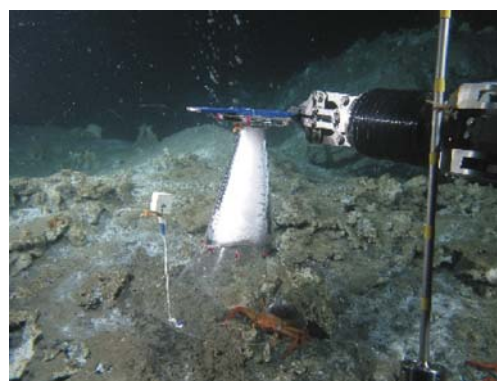


Photo Hydrated methane gas bubbles.

first riser test of the Chikyu, which was conducted off Shimokita in 2006, this research group made an evaluation, by the culture method and molecular biology techniques, of the microbial phase in the circulation mud fluids before and after riser drilling. This research is only possible in the first trial. This study yielded important knowledge, including the fact that the current chemical composition of the mud fluids does not adequately control the multiplication of external microorganisms, and designated subsurface microorganisms multiplied in the mud fluid tank after circulation (Masui, Morono & Inagaki, *Geomicrobiol. J.* 2008). In the future, detailed studies will be carried out, including a further quality evaluation of microbial samples, development of an aseptic sampling method with frozen samples, and a quality evaluation using different storage methods.

3 Core Sampler Curation System and Start of Full-Scale Operation of Facilities and Equipment

The Kochi Institute began receiving of drilling cores for the ocean areas for which Japan is responsible, as agreed by the IODP-SPC (Integrated Ocean Drilling Program-Science Planning Committee), and began preparations to receive core samples obtained by JAMSTEC's vessels, and other devices. During this fiscal year, legacy cores with a total length of approximately 84 km, which were taken by the Glomar Challenger and JOIDES (Joint Oceanographic Institutions for Deep Earth Sampling) Resolution under the Deep Sea Drilling Project/Ocean Drilling Program (DSDP/ODP), and had been managed by storage facilities in the United States, were succes-

sively transferred to the Kochi Core Center, which is operated jointly by the Kochi Institute and Kochi University. In addition, approximately 3,400 m of core samples taken by the Chikyu in the IODP's Nankai Trough Seismogenic Zone Experiment (NanTroSEIZE) were delivered to the Institute on February 14, 2008.

Accompanying this, the Kochi Institute began preparations to implement a sample management system (curation system), including staffing and management methods. Studies on core management were carried out inside and outside JAMSTEC, and with other countries as well as Japan, toward the development of support software (Core-Kura) for accurate control of a huge number of samples and the implementation of management methods for JAMSTEC samples and others. In cooperation with JAMSTEC's Center for Deep Earth Exploration (CDEX), a large-scale moving rack system for core sample storage was newly constructed in No. 2-No. 4 Refrigerated Repositories. In addition to this, 20-foot containers were allocated for use in transportation of samples, etc. with the Chikyu, a new yard was constructed, and roadways were expanded and various kinds of equipment were allocated for receipt of the legacy cores.

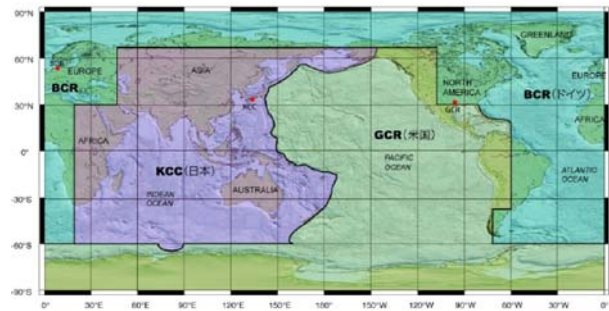


Figure Core samples taken from the ocean areas shown in purple were all transported to the Kochi Core Center for storage and management.



Photo Approximately 3,400 m of core samples taken by the deep-sea drilling vessel Chikyu as part of the Nankai Trough Seismogenic Zone Experiment (NanTroSEIZE) were delivered to No. 4 Refrigerated Repository at the Kochi Core Center.

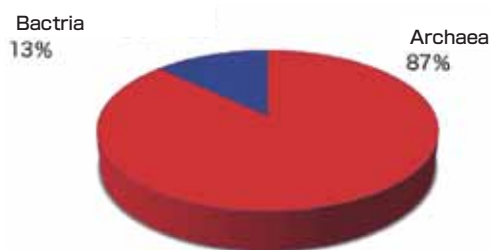
4 Outreach Activities

(1) Special Open-House for Chikyu

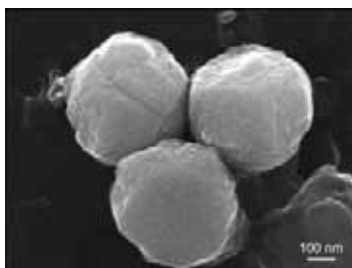
A special open-house event was held for the Chikyu at Kochi New Port on Wednesday, February 13, 2008. A total of 127 persons, including governmental authorities in Kochi Prefecture, high school students, and university-related persons specializing in earth sciences participated. By holding this event, the Kochi Institute was able to contribute to a deeper understanding of the activities of JAMSTEC in Kochi.

(2) General Open House Events at the Kochi Institute for Core Sample Research

The theme of the Kochi Institute's one-day open house, which was held on Saturday, November 3, 2007, was "See, Touch, and Understand the World of the Sea Bottom - The Strange Experience of Earth and Sea -." Beginning with an introduction of the deep-sea drilling vessel Chikyu and the Nankai Trough Seismogenic Zone Experiment (NanTroSEIZE), the event featured an exhibition of boring cores from approximately 3.2 billion years ago, experience of subsurface pressure, etc., allowing visitors to enjoy science in a familiar way. The event attracted many visitors, who numbered 650 person



Percentage of complete polar lipids extracted from sediment samples



A scanning electro-microscope image of micro-organisms in the sediment core samples extracted off Shimokita by the Chikyu.

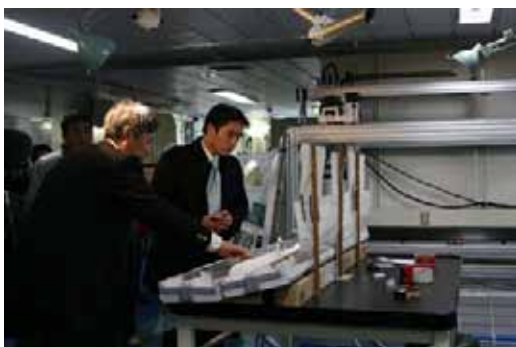


Photo The Governor of Kochi Prefecture receiving an explanation of core samples.



Photo A curator answers a question from a visitor.



Photo An exhibition in the Entrance Hall



Photo A researcher explaining a subsurface pressure experience.

(5) Global Oceanographic Data Center

1 Outline of Activities

The Global Oceanographic Data Center (GODAC) was established for the purposes of promoting the development of human resources in multimedia fields and attracting information and communications-related companies and creating employment in the northern part of Okinawa Prefecture, which are being promoted by Nago City, Okinawa Prefecture. Since 2001, GODAC has been operated by JAMSTEC under a management commission. Its activities include digitalization, arrangement, and storage (digital archiving) and supply of the precious deep-sea images obtained by JAMSTEC's manned research submersibles and unmanned exploratory vehicles, as well as JAMSTEC's periodical publications and other materials. The Center's facilities and equipment are open, free of charge, to promote understanding of marine science and technology.

2 Digital Archive (Conversion of Data to Electronic Media and Organization/Storage) and Information Dissemination

In cooperation with JAMSTEC's Yokohama Institute for Earth Sciences (YES), GODAC operates and manages the GODAC system, high resolution video supply system, and network security. Since FY 2007, the infrastructure system for the Biological Information System for Marine Life (BISMaL) has also been created (Photo 1).

As results of digital archiving work for FY 2007, the Center encoded 1,907 deep-sea videos taken by the manned research submersible Shinkai 6500 and others, and created 28,971 shots as indexing work, inputting various types of information as image data divided into shots. Up to the end of March 2008, approximately 14,000 shots of deep-sea images were available at the GODAC website (Earth's Environment Portal Site).

As digital processing of printed matter, GODAC has digitalized and made available 15,806 pages of various periodical



Photo 1 Construction of the infrastructure system for the Biological Information System for Marine Life (BISMaL).

publications, including the JAMSTEC Newsletter "Natsushima," "Mirai" cruise reports, and others. In addition to these, the Center has digitalized and makes available 730 graphic-type items, such as cruise tracks, the prize-winning entries in the 10th National Children's Picture Contest "Ocean Dream Picture Postcard," etc.

GODAC also performed database-related work such as support for the construction of a rock database, support for the construction of a press release materials database, etc., and manages and operates GODAC websites, including the Earth's Environment Portal Site, the Coral Reef Network web system, and others. In particular, the Coral Reef Network web system was renovated in March 2008, and began distributing not only photographs of coral reefs, but also moving pictures photographed by the underwater compact TV camera robot (ROV) owned by GODAC (Photo 2). GODAC websites have been accessed approximately 1.43 million times.

3 Increasing Understanding of Marine Science and Technology (Public Relations)

To increase understanding of marine science and technology and for popularization/education of residents of the region, GODAC opens its facilities and equipment, including the Conference Room in the users' Public Area and user terminals (personal computers) and allows local children to use these facilities. The Center also employs various types of contents, such as videos, poster panels, and models, to explain marine science and technology and global environment change, centering on the research achievements of JAMSTEC. In November, the exhibition in the Public Area was renewed, and a Planning Corner was created. Four special exhibits were presented, "Special Exhibit Commemorating the 1000th Voyage of the Shinkai 6500," "Dangerous Sea Life," "Frontline of Earthquake Observation," and "What is a Coral Reef?"



Photo 2 Renovated Coral Reef Network web system.

The number of visitors in FY 2007 totaled 13,768, which was an all-time high, and on September 26, the cumulative total of visitors reached 60,000 persons (Photo 3).

As popularization/educational activities for the general public, the Center held 5 seminars on marine science and technology (May 12, May 31, July 22, December 1, and January 15). For children, the Center also held three "Seaside Classrooms," combining beachcombing and handicrafts. Other activities included experience in maneuvering the compact underwater TV camera robot owned by GODAC (Photo 4).

On May 12, GODAC held a general open house of its facilities, and received 156 visitors.

The marine science and technology school "Coral Reefs of the Beautiful Sea and Global Environmental Change" sponsored by the GODAC Public Relations Division over a 3-day period (March 10-12) was the first event of its kind in Okinawa, and used GODAC and Nago City's North Lifelong Learning Center as its sites.

Among other activities, GODAC also cooperated in exhibitions at various events in Okinawa. The main events are listed below (Photo 5).

- ・ Free Research on the Sea and Fish" (sponsored by Asahi Gakusei Shinbunsha (Student Newspaper Co.)), experience maneuvering ROV and tour of GODAC facilities (July 26).
- ・ Tsushimamaru Memorial Service (sponsored by Tsushimamaru Memorial Association), special lecture (August 22).
- ・ National Industrial Education Fair (sponsored by Ministry of Education, Culture, Sports, Science and Technology (MEXT), Okinawa Prefecture, Okinawa Education Council, etc.), exhibition including experience maneuvering ROV and pressure experiment, etc. (November 23-24).
- ・ Nago Cherry Festival (sponsored by the Nago City Tourist Association), exhibition booth, video recording (January 26-27).
- ・ Girl Scout Kyushu Camp (sponsored by the Kyushu District of the Girl Scouts of Japan), experience maneuvering ROV and beachcombing and handicrafts classroom (March 26).

In its work experience training and internship program, GODAC received a total of 41 students from 13 schools, centering on elementary, middle, and high schools and universities in northern Kyushu.



Photo 3 GODAC receives its 60,000th visitor (cumulative total).



Photo 4 "Seaside Classroom" (beachcombing and handicrafts classroom).



Photo 5 GODAC's exhibition booth at the Nago Cherry Festival.

10. International collaboration

Ocean observation and research on a global scale is required to deal with the issues of global-scale environmental variations including climatic change.

To elucidate these issues and promote ocean observation and research more effectively and efficiently, JAMSTEC is striving to promote joint international projects, and to maintain and establish good cooperative relationships with United Nations organizations, international organizations, and research organizations in other countries.

(1) International organizations

JAMSTEC sends experts to various task forces in the IOC (Intergovernmental Oceanographic Commission) of UNESCO (United Nations Educational, Scientific and Cultural Organization) to support their activities, and studies the international requirements necessary for smooth implementation of ocean observations and research under the provisions of the Law of the Sea. In January 2008, an "IOC Cooperation Promotion Committee" was established in JAMSTEC with the aim of strengthening its research program promotion system for international research projects related to the IOC.

JAMSTEC is a member of SOPAC (South Pacific Applied Geoscience Commission), an influential commission in the South Pacific region, which is one of its major observation and research areas. JAMSTEC is also a member of POGO (Partnership for Observation of the Global Oceans), a forum of major oceanographic research institutions around the world. Upon the request, JAMSTEC sends researchers to other oceanographic international organizations to contribute to their research activities.

(2) International joint projects

JAMSTEC participates in the following international joint projects and activities.

- ・ The Array for Real Time Geostrophic Oceanography (ARGO)
- ・ The Climate Variability and Predictability Program (CLIVAR)
- ・ Global Ocean Observing System (GOOS)
- ・ International Continental Scientific Drilling Program (ICDP)
- ・ The International Margins Program (InterMARGINS)
- ・ An initiative for international cooperation in ridgecrest studies (InterRIDGE)
- ・ Integrated Ocean Drilling Program (IODP)
- ・ North Pacific Marine Science Organization (PICES)
- ・ Global Earth Observation System of Systems (GEOSS)

(3) Cooperation under the Intergovernmental Cooperative Agreement

JAMSTEC conducts cooperative research based on the Intergovernmental Cooperative Agreement concluded among the United States, the United Kingdom, Italy, India, Australia, Canada, South Korea, China, Germany, France, Russia, the EU and Japan.

The intergovernmental cooperative task force held in FY2007 was as follows:

- ・ June 2007 2nd Japan-New Zealand Economic Working Group
- ・ October 2007 10th Japan-Canada Joint Science and Technology Cooperation Council
- ・ December 2007 22nd French-Japanese Ocean Development Sub-Committee
- ・ February 2008 12th Japan-China Science and Technology Cooperation Council

(4) Cooperation with foreign institutions

Under the memorandums and agreements signed with the institutions concerned in the United States, the United Kingdom, India, Indonesia, Australia, Canada, Republic of Korea, Germany and France, JAMSTEC provides inter-organizational research cooperation.

(5) Others

In May 2007, Prince Andrew, Duke of York of England's

Royal Family visited JAMSTEC, where he toured the Earth Simulator at the Yokohama Institute for Earth Sciences (YES) and spoke informally with English researchers. After moving to the Yokosuka Headquarters, Prince Andrew viewed the deep-sea cruising vessel Urashima and the manned research submersible Shinkai 6500. In November, President Rüdiger Wolfrum of the International Tribunal for the Law of the Sea visited JAMSTEC and exchanged views on "Treatment of Marine Genetic Resources in International Waters" under the enforcement of the United Nations Convention on the Law of the Sea, and viewed JAMSTEC's facilities, centering on the Extremobiosphere Research Center.

Also in November, the 4th Annual Meeting of the Group on Earth Observations (GEO) and a Cabinet Summit were held in Cape Town, Republic of South Africa. A Japanese delegation of 25 persons attended, headed by Kisaburo Tokai, Minister of Education, Culture, Sports, Science and Technology. Two representatives from JAMSTEC (Institute of Observational Research for Global Change: IORGC) attended the GEO meeting. An exhibition was also presented on the construction of the Hydrometeorological Array for Isv-Monsoon Automonitoring (HARIMAU; under the MEXT Global Earth Observation System of Systems: GEOSS), which is being carried out by JAMSTEC.

In February 2008, Dr. Patricio Bernal, Executive-Secretary of the IOC visited the Yokosuka Headquarters and toured the facilities.

Country	Research institution	Conclusion status	Joint research subjects
US	Woods Hole Oceanographic Institution (WHOI)	From June 4, 2002 to June 3, 2007 (Under renewal process)	1) Marine geology and geophysics 2) Research on polar regions 3) Biogeochemistry and carbon cycle 4) Marine physics and WOCE line re-observation 5) Geochemical evolution of Solid Earth 6) Submersible engineering and safety 7) Deep-sea floor observation station 8) Operating information
	Scripps Institution of Oceanography (SIO)	From December 19, 1996 (Automatically renewed by 5 years)	1) Research on the ocean general circulation and climate 2) Research and development on ocean acoustic tomography 3) Research and study on distortion of the sea-floor plate of the Pacific Ocean 4) Research on adaptation mechanism of micro-organisms to deep-sea environment 5) Research on thermal and material flux on ocean-floor
	Lamont-Doherty Earth Observatory (LDEO)	From December 7, 1997 (Automatically renewed by 5 years)	1) General information exchange 2) Scientific information exchange and personnel exchanges a) Marine physics and thalassiochemistry b) Marine Solid Earth Science (oceanic earthquake and ocean drilling program)

	Pacific Marine Environmental Laboratory of the National Oceanic and Atmospheric Administration (PMEL/NOAA)	From December 15, 2002 to June 14, 2008 (Under renewal process, extended for 6 months)	1) Cooperation on maintenance of TRITON buoy/TAO array 2) Ocean and climate research 3) Ocean and atmospheric monitoring 4) Data management 5) general information exchange
	Monterey Bay Aquarium Research Institute (MBARI)	From March 18, 2008 to March 17, 2013	1) Ecology and evolutionary research on deep ocean floor organisms and middle depth marine organisms 2) Development of video image analysis and database 3) Development of deep-sea observation device 4) Exchange of general information and scientific information
	Texas A & M University (TAMU)	From October 23 2007 to October 22, 012 (Automatically renewed by 5 years)	1) Marine drilling 2) Global ocean circulation/climate change 3) Analysis of features of crustal movement 4) Microbiological gas hydrates in deep-sea biosphere
	University of Hawaii (UH)	From April 1, 2004 (April 28) to March 31, 2009	Contract research on the International Pacific Research Center (IPRC)
	University of Alaska (UA)	From April 1, 2004 (April 28) to March 31, 2009	Contract research on the International Arctic Research Center (IARC)
	IODP Management International, Inc. (IODP-MI)	From October 1, 2004 to March 31, 2009	Planning of activities for Integrated Ocean Drilling Program (IODP) with the IODP Management International, Inc. (IODP-MI) and establishment of a formal framework on implementation of the activities
UK	Southampton Oceanography Centre (SOC)	From March 25, 2002 to March 24, 2007	1) Geology and geophysics 2) Marine physics 3) Thalassiochemistry 4) Underwater technology 5) Atmospheric and ocean simulation 6) Information exchange
India	National Institute of Oceanography (NIO)	From May 31, 2000 to December 4, 2011	1) Ocean observation associated with climate research 2) General information exchange
Indonesia	Indonesia Agency for the Assessment and Application of Technology (BPPT)	From November 20, 2000 to July 10, 2011	1) Research on tropical marine climate change 2) Research on climate dynamics in maritime-continental region 3) Deep-sea research on geology/geophysics and biology
Australia	Commonwealth Scientific and Industrial Research Organization (CSIRO)	From August 6, 2003 to August 5, 2008	1) Research on thermal and material flux related to the ocean circulation and its variation 2) Research on carbon dioxide balance on the Indian Ocean 3) Distribution of chlorofluorocarbons on the South Pacific Ocean 4) General information exchange
Canada	Department of Fisheries and Oceans (DFO)	From March 20, 2000 (Automatically renewed)	1) Observation and model research on ocean climate change in the upper undersea layer of 200 to 300m of the Arctic Ocean 2) Physical, scientific and biological observation of interaction of the continental shelf and the sea basin and its model research 3) Observational research on balance of freshwater and chemical components on the Bering Sea, the Chukchi Sea, and the Beaufort Sea 4) Observation and model research on variation of ice thickness distribution on the continental shelf and the sea basin

Korea	Korea Ocean Research & Development Institute (KORDI)	From September 18, 2002 (Automatically renewed by 5 years)	1) Geological and geophysical research of the peripheral sea of oceanic trenches 2) Technical development of remotely operated undersea vehicle 3) Deep-sea biocenoses 4) Use of deep-sea water 5) Diversification of deep-sea micro-organisms and isolation method of individual species 6) General information exchange
	Korean Institute of Geology, Mining and Materials (KIGAM)	From March 11, 2008 to March 10, 2013	1) Research in connection with Integrated Ocean Drilling Program (IODP) 2) Preparation for construction of scheme for research in seismology and mutual exchange of data 3) Analysis of core samples 4) Others
Germany	Earth Science Center in Potsdam (GFZ)	From October 5, 2006 to October 4, 2011	Implementation, management and operation of ICDP (International Continental Scientific Drilling Program)
	Alfred Wegener Institute for polar and marine research (AWI)	From July 5, 1995 (Automatically renewed by 5 years)	1) Deep-sea research and technology a) Research on deep-ocean floor environment and development of its methodology b) Development of deep-sea technology (2) Polar-region science and technology a) Marine physical instruments and observation b) Polar-region oceanography and related mooring technology
France	French Institute of Research and Exploitation of the Sea (IFREMER)	From December 5, 2007 to December 4, 2012	1) Marine technologies 2) Marine monitoring 3) Microorganisms 4) Deep ocean floor observation 5) Simulation research using Earth Simulator 6) Ecosystems and hydrothermal vents at continental margin 7) General information exchange

Chapter 2. Results of FY2007 Activities

I. Measures to be taken to achieve the objectives for improving the quality of services and other operations provided to the public

1 Fundamental research and development concerning ocean science and technology

1.1 Promotion of key research activities

1.1.1 Observational Research for Global Change

(1) Climate Variations Observational Research Program

The objective of the Climate Variations Observational Research Program is to develop an extensive and continuous ocean observing system in the Pacific and Indian Ocean, to reveal the mechanisms of the variations in the upper layer with annual to decadal time scales. The Tropical Ocean Climate Group focuses mainly on the phenomena that occur in the warm water pool of the western Pacific and the eastern Indian Ocean while the Argo Group focuses mainly on interannual to decadal variations in the north Pacific. In order to further facilitate these research activities, under the cooperation with various international organizations, we will continue to develop the TRITON buoy mooring network in the equatorial Pacific and the Indian Ocean as well as developing the Argo float array with a focus on the mid-latitude regions of the both oceans.

Tropical Ocean Climate Group

Tropical Ocean Climate Group continued the observations in the western tropical Pacific and the eastern tropical Indian Ocean by using the TRITON buoy array and sub-surface ADCP moorings. Two cruises in the western tropical Pacific and one cruise in the east tropical Indian Ocean were conducted by R/V MIRAI under the cooperation with the Marine Technology

Center of JAMSTEC. During these three cruises, total of 15 TRITON buoys in the western tropical Pacific were recovered/deployed and 2 TRITON buoys in the east Indian Ocean were recovered. Also starting this year, 2 m-TRITON buoys funded directly by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) were deployed replacing the TRITON buoys. The mooring location of the TRITON/m-TRITON buoys and sub-surface ADCP buoys were shown in Fig. 1.

XCTD/XBT observations in the northern Indian Ocean were conducted by using the volunteer observation ships. The data obtained by this observation is delivered to the meteorological institutions in the world by GTS and is open to the public after the quality control. Some of the major results of analyzing these data obtained are introduced below.

a. Zonal gradient of sea surface temperature and variation of Pacific warm pool associated with cooling in the western Pacific before the onset of El Niño.

In order to clarify a role of interaction between the atmosphere and the ocean over the warm pool in the western tropical Pacific in the mechanism of onset of El Niño, upper ocean temperature variation around warm pool region west from 156°E (hereafter, FWEP) where the TRITON buoys were deployed was investigated from boreal winter of 2001 to boreal spring of 2002 before the onset of the 2002/03 El Niño.

Satellite data indicates that negative sea surface temperature anomalies are developed in the east coast of New Guinea before the onset of the 2002/03 El Niño (December, 2001) to expand eastward in a wide area of the western equatorial Pacific (Fig. 2). At this time the sea surface temperature in FWEP showed a positive zonal gradient with enhancement of westerly wind anomalies to start moving the Pacific warm pool eastward, followed by the onset of the 2002/03 El Niño.

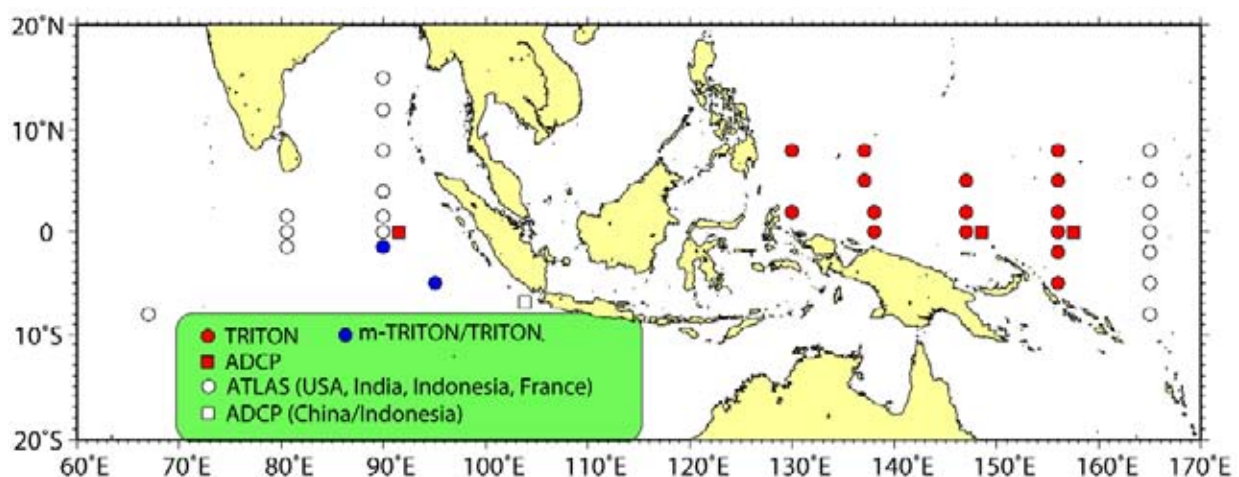


Fig. 1 Mooring location of the buoys as of January, 2008. Red and blue solid circles indicate the buoys by JAMSTEC and the empty white circle indicates the Atlas buoys by NOAA of USA.

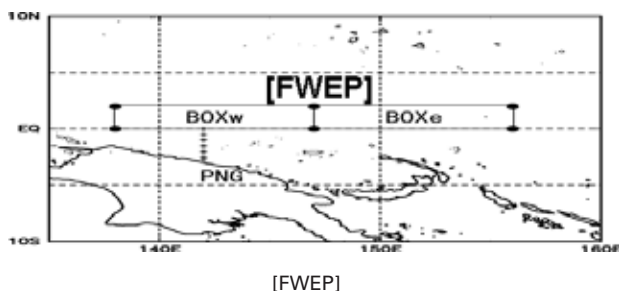


Fig. 2 Regions covered by the present analysis. Black solid circles indicate location of the buoys used in analysis. Plus mark indicates the CTD observational site by the research vessel "KAIYO."

Heat budget analysis in the mixed layer was done using the TRITON buoy data in order to investigate the mechanism of the sea surface temperature cooling in FWEF (Fig. 3). The mixed layer temperature decreased in its value from early December of 2001 to early January of 2002 and a strong cooling effect (about $-0.01^{\circ}\text{C/day}$) was observed in zonal heat advection. This relates to positive zonal gradient of the mixed layer temperature and also eastward current, and can explain approximately 50% of the temporal change rate of the mixed layer temperature. On the other hand cooling effect by the net surface heat flux is only $-0.005^{\circ}\text{C/day}$ and warm effect from it was found in a certain period. Cooling effect was not found in the zonal heat advection when the mixed layer cooling was not found. These results indicate that zonal heat advection plays a key role in cooling the mixed layer in BOXe. Similar results were also obtained in BOXw. CTD observation by the research vessel "KAIYO" affiliated to JAMSTEC further shows the temperature structure indicating the coastal upwelling along the east coast of New Guinea, i.e., the upstream of FWEF, in the period when the negative sea surface temperature anomalies was developed.

The results of the present study show a possibility that negative anomalies of the sea surface temperature, which is caused

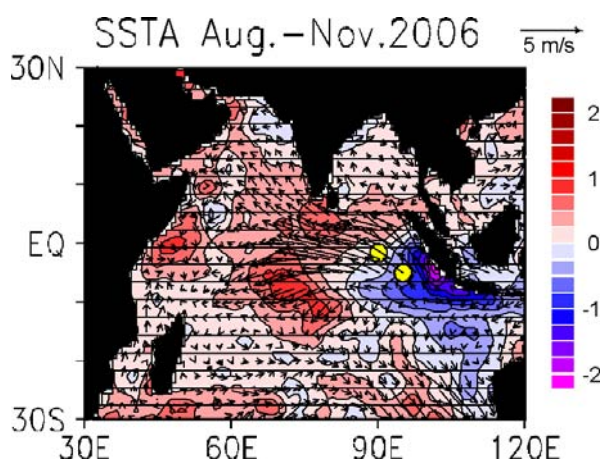


Fig. 4 SST and sea surface wind anomalies averaged from August to November 2006. The SST data is taken from the National Oceanic and Atmospheric Administration Optimum Interpolation dataset (Reynolds et al., 2002), while the sea surface wind data is obtained from the product of the QuickSCAT satellite. Yellow circles indicate the location of TRITON buoys.

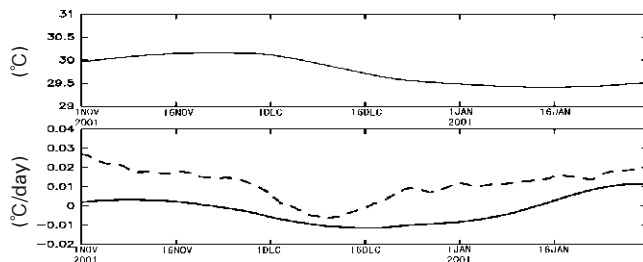


Fig. 3 Results of the heat budget analysis in BOXe. The solid line in an upper panel indicates time series in mixed layer temperature. The solid line in a lower panel indicates a temporal change rate in mixed layer temperature induced by zonal heat advection ($^{\circ}\text{C/day}$). The broken line in a lower panel indicates a change rate in mixed layer temperature by a net sea surface heat flux ($^{\circ}\text{C/day}$).

by coastal upwelling along the east coast of New Guinea, expands to a wide area of FWEF by the negative zonal heat advection related to eastward current. This implies that coastal oceanic dynamics was important in the SST variation in the FWEF, which affects the onset of the 2002/2003 El Niño, in addition to the cooling effect by the net surface heat flux which is previously considered to be important to the sea surface temperature cooling.

b. Heat balance of surface mixed layer in the eastern tropical Indian Ocean

A Indian Ocean Dipole (IOD) phenomena occurred from August to November 2006 in the Indian Ocean (Fig. 4). The 2006 IOD became the first event, whose subsurface structure was partly observed by two TRITON buoys. We investigated the temperature variation in the surface mixed layer in the eastern Indian Ocean to clarify the processes that produced the anomalous SST variation in 2006. Analysis was conducted at an intraseasonal time scale and focused on (5°S , 95°E) where in situ measurements by the TRITON buoys were available. Heat-balance analysis demonstrated that air-sea heat fluxes and horizontal heat advection mainly accounted for the mixed layer temperature variation (Fig. 5). The results indicate that the relative importance of the heat fluxes and horizontal heat advections changed remarkably with the onset of the IOD. During January to mid-August 2006, before the onset of the IOD, the temperature variation was mainly explained by the net surface heat flux at an intraseasonal time scale. During the IOD in late-August to November 2006, the southwestward horizontal temperature gradient and the surface current produced large horizontal heat advection that exceeded the contribution of surface heat fluxes. These results confirm the importance of oceanic processes in the evolution of the IOD, and the heat balance analysis would be a fundamental example in validating model outputs for the Indian Ocean.

c. Comprehensive statistical analysis for upper ocean currents

in the equatorial Indian Ocean

Since ocean currents data observed with ADCP moorings deployed on the equator in the eastern Indian Ocean by National Institute of Oceanography, India and by Pacific Marine Environment Laboratory/National Oceanic and Atmospheric Administration, U.S.A. are available through international cooperation, we can acquire zonal structure of current profile on the equator from 80°E to 90°E, corresponding to off the coast of south of India to that of Sumatra. Using these data we conducted comprehensive statistical analysis for upper ocean currents. Basically the mean currents indicate vertically 2-layer structure; one velocity core appears around 60 m and the other appears around 120 m, corresponding to the equatorial undercurrent. 30-50 days signal in the uppermost layer and semiannual signal in the region of equatorial undercurrent are dominant for the zonal current, whereas about 14 days signal corresponding to the mixed Rossby-gravity wave is dominant for the meridional current. We also investigated wave-propagating character from phase relationship between current property off the coast of south of India and that of the coast of Sumatra. The 35-day signal, which is predominant in the uppermost layer, propagates eastward with a phase velocity of 6.4 m s⁻¹. We suggest that this signal is caused by atmospheric disturbances. The semiannual signal, which is predominant in the region of the equatorial undercurrent, propagates eastward with a phase velocity of 2.4 m s⁻¹, corresponding to the Kelvin wave

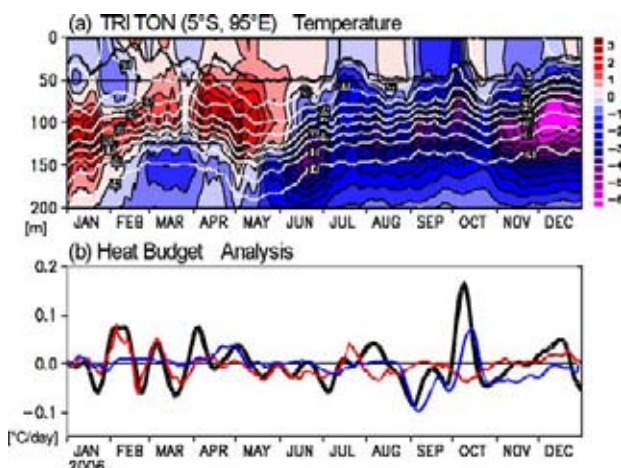


Fig. 5 (a)Time-depth section of the ocean temperature observed by the TRITON buoy at 5°S, 95°E. Colors (contours) denote anomalies (raw values). Contour interval is 2°C. The black line indicates the mixed layer depth. (b)Terms of the mixed layer temperature balance. The black line indicates temporal change of mixed layer temperature, the red line indicates contribution of net sea surface heat fluxes, and the blue line indicates contribution of the horizontal heat advection. The unit is °C/day. Terms of the mixed layer temperature balance (1) [°C/day]: (a) temporal change ($\partial T/\partial t$, black) and net heat fluxes ($Q_{net}/C_p H$, red); (b) $\partial T/\partial t$ (black) and zonal ($-UT_x$, red) and meridional ($-VT_y$, blue) horizontal heat advection and their sum ($-UT_x - VT_y$, green); and (c) $\partial T/\partial t$ (black) and the sum of $Q_{net}/C_p H$ and $-UT_x - VT_y$ (gray). Also shown in (d) is the time-depth section of temporal change in ocean temperature and the MLD. In (a)-(c), light shading indicates the errors in the analysis. Details of the error estimation are presented in the Appendix.

of first baroclinic mode.

d. Development of the new observation system

In the development of a high accuracy TRITON buoy, the measurement of sea surface temperature was conducted by using the TRITON buoy at Equator 156°E under the cooperation with the Tohoku University. With the parallel operation of a large number of the next generation buoys and a small number of the high accuracy reference buoys, the development of the surface buoy network in the tropical region has progressed one step forward for the efficient operation of the buoys and to satisfy the needs of more advanced research.

Argo Group

As one of the leading groups in the international Argo community, Argo Group is responsible for the deployment of Argo floats mainly in the north Pacific and for the operation of the PARC (Pacific Argo Regional Center). Argo float data is released both in real-time and in delayed mode. After receiving data from the Argos satellites, Japan Meteorological Agency releases it as real-time data to the worldwide meteorological organizations via GTS (Global Telecommunication Systems) within 24 hours, and Argo Group carries out high level quality controls to the Argo float data and sends it as delayed-mode data to GDAC (Global Data Assembly Center) within a year. Both real-time and delayed-mode data are available to anyone in the world by accessing to GDAC via internet with no charge. Using Argo float data, Argo Group conducts observational researches on several themes in the north Pacific such as seasonal to inter-annual variations, the subduction process, the formation and transport processes of several types of mode waters, temperature and salinity variations in the subtropical and tropical regions, and the oceanic structure in the subarctic region. Argo Group is also developing a next-generation float.

a. Deployment of Argo floats

According to the deployment plan of FY2007, Argo Group deployed 80 floats in the Pacific, Indian, and Southern Oceans. At present, 348 Argo floats owned by JAMSTEC are working well. By the great international cooperation, the global Argo float network attained the initial target of 3,000 floats at the end of October 2007 and maintains the same level in March 2008 (Fig.1-6).

b. Delayed-mode quality control of Argo float data and operation of PARC

Argo Group released about 12,000 profiles as real-time data and about 16,000 profiles as delayed-mode data. PARC, which started in 2005, plays an important role to maintain the

level of the delayed-mode quality control of all Argo floats deployed in the Pacific by any organizations. Argo Group supplied its know-how about delayed-mode quality control to the researcher responsible for delayed-mode processing in Korea and helped researchers in India to revise the high quality reference dataset in the Indian Ocean.

Furthermore, one of the researchers of Argo Group was designated as a chair of a newly set international working group to tackle with several issues of oxygen sensors loaded on Argo floats.

c. Anticyclonic eddy moving westward in Alaskan Stream and



Fig. 6 Distribution of global Argo floats (3,129 floats, as of March 2008).

its structure

Argo data were analyzed together with the satellite altimeter data on sea level variation to clarify behavior of the anticyclonic eddy moving westward in the Alaskan Stream which was considered to play an important role in heat, freshwater and mass transfers and biological processes in ocean circulation of the northern Pacific subarctic zone and the structure of its water mass. Fifteen eddies were identified by analysis of the sea level anomaly data and it was shown that eddies were formed not only in the Gulf of Alaska but also in the southern coast of the Aleutian Islands and part of them reached the ocean circulation in the western subarctic zone (Fig. 7). It has been reported that anticyclonic eddy in the Gulf of Alaska moves while holding the water entrained during its formation. However, eddies were observed by Argo floats west of 160°W where vessel observation was not reported to find the loss of water mass characteristics when formed (Fig. 8). Using the Argo data, heat and freshwater fluxes of the eddies, which were separated from the Alaskan Stream to enter into the ocean circulation in the western subarctic region were estimated to reveal good match with sea surface heat and freshwater fluxes in the same region. This result in the present study is a good example, in which effect of a medium scale eddy on a large scale field through heat and freshwater transfers can be estimated by analysis of the Argo data effectively combined with the satellite data.

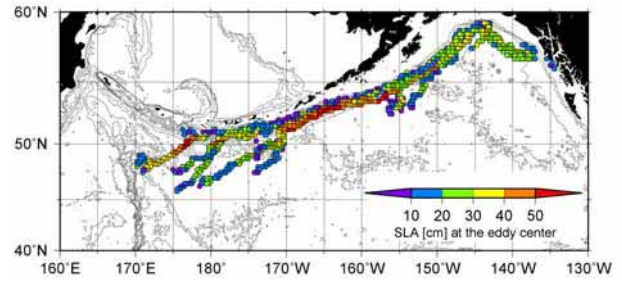


Fig. 7 Trajectory of anticyclonic eddies moving westward in the Alaskan Stream and having a life time longer than a half year, which were identified by the sea level anomaly data (provided by AVISO, seven days interval from 1992 to 2006). Variation of sea level anomaly at a center of eddies is colored.

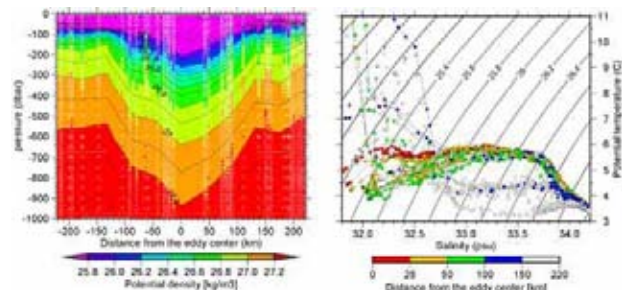


Fig. 8 Composite cross-sections of anticyclonic eddies by Argo data. Cross-section of potential density is shown in a left diagram. Time series diagram color-coded by a distance from a center of eddies is shown in a right diagram.

d. Relation between vertical diffusion of Subtropical Mode Water and biological production

Considerably large and persistent vertical diffusivity (up to $5 \times 10^4 \text{ m}^2 \text{ s}^{-1}$) near the upper end of Subtropical Mode Water (STMW) was suggested recently. A profiling float equipped with chlorophyll and oxygen sensors was used for observation to confirm this idea. The floats deployed in March, 2006 in the formation region of STMW south of the Kuroshio Extension was trapped by an anticyclonic eddy which contained STMW to drift until July. Accordingly, seasonal evolutions of STMW and the seasonal pycnocline and their relation with concentration of chlorophyll and dissolved oxygen were successfully captured (Fig.9). Concentration of chlorophyll near the sea surface was reduced after April when the seasonal pycnocline was formed and nutrients near the sea surface were depleted. On the other hand, a layer with high concentration of chlorophyll was continuously distributed in the subsurface layer and dissolved oxygen was increased. A lower limit of this high concentration layer always agrees with an upper end of STMW. These facts strongly suggest continuous upward feed of nutrients from STMW and existence of primary production maintained by this support. From this float observation together with the results of vessel observation in the float observational region, it has been shown that enough nutrients can be fed to support this produc-

tion by the large vertical diffusivity suggested by the previous research (Fig.10). It is generally very difficult to estimate vertical diffusivity in the open ocean, which is important in various physical, biological and chemical processes in the ocean. However, results obtained here indicate observation by floats with sensors to measure biological and chemical parameters is also effective in consistent estimation of diffusivity.

e. Development of next generation float

Argo Group is developing a next-generation float with a buoyancy control system combining an oil pump and a plunger.

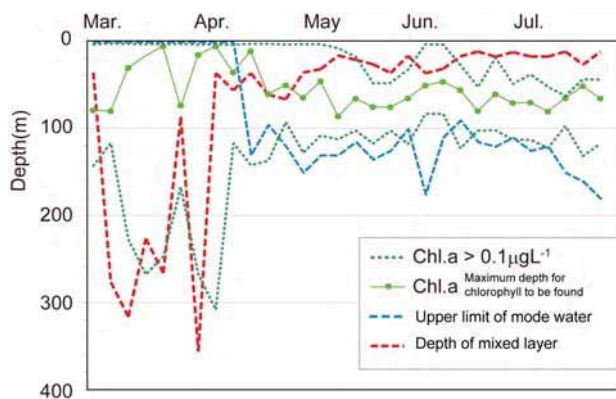


Fig. 9 Time series of a layer with high concentration of chlorophyll (layer with concentration higher than $0.1 \mu\text{g/l}$), depth with maximum concentration of chlorophyll, an upper end of STMW and mixed layer depth measured with floats with chlorophyll and oxygen sensors.

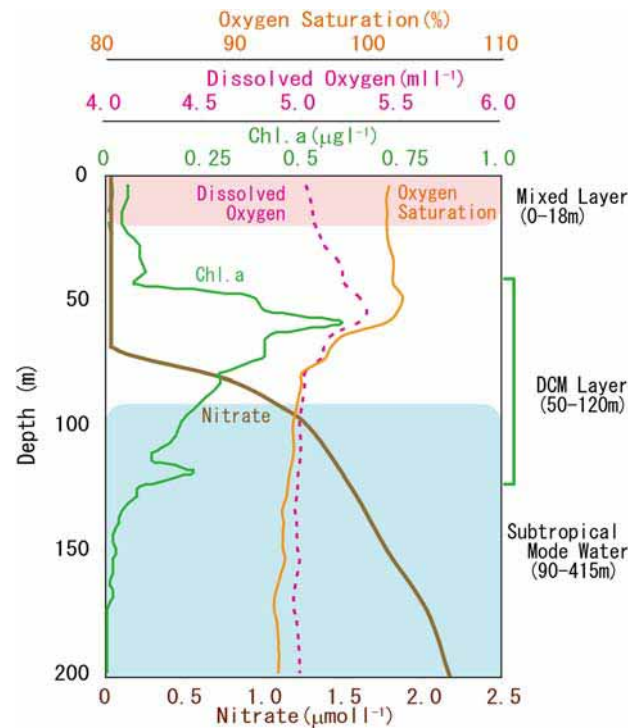


Fig. 10 Schematic diagram to show relation of vertical density structure with nutrients, concentration of chlorophyll and dissolved oxygen based on float data and shipboard water sampling data. Nutrients (nitrate) in the STMW layer (layer in green color) is transported upwards by strong vertical diffusion to feed to the seasonal pycnocline (layer in white color), which maintains primary production represented by the layer of maximizing chlorophyll (Chl. A) concentration and dissolved oxygen.

(2)Hydrological Cycle Observational Research Program

As Hydrological Cycle Observation Research, detail land and atmospheric observation using towers, AWS, radar and GPS and others at the region from Siberia, Palau Islands to Indonesia in Eastern Eurasia/West Pacific region were implemented, and high quality observation data was obtained. Stable isotope and data-opening, as common work for groups, were done satisfactory. Also, as part of international collaboration which is essential for global observation, international projects related to CliC (Climate and Cryosphere) and MAHASRI (Monsoon Asian Hydro-Atmosphere Scientific Research and Prediction Initiative) were done. The obtained data was opened through the home-page of the IORGC and MEDID of JAMSTEC.

Large-scale Hydrological Cycle Group

The main research activities in the Large-Scale Hydrological Cycle Group have been conducted in the Maritime Continent region and the Indochina peninsula. The GEWEX/WCRP international research project, MAHASRI (Monsoon Asian Hydro-Atmosphere Scientific Research and prediction Initiative), and AMY (Asian Monsoon Year) as a part of the WCRP cross-cutting initiative of the International Monsoon Studies (IMS), has been lead by the Group leader, Dr. Jun Matsumoto.

Radar and profiler data over the Indonesian maritime continent has been obtained in collaborated with the JEPP (Japan EOS Promotion Program)-HARIMAU (Hydrometeorological ARray for ISV-Monsoon AUtomonitoring) project under the leadership of Dr. Manabu Yamanaka. The second campaign observation of JEPP-HARIMAU (HARIMAU2007) was conducted with dual X-band Doppler Radars (XDRs) during April to May, 2007 in Western Sumatera, and precipitation systems in the transitional stage from the rainy to the dry season were observed (Fig.1).

Our group investigated the relationships between local circulations and large-scale phenomena, such as annual and seasonal monsoon variation, intra-seasonal oscillation, and heavy rainfall in Vietnam, Kalimantan and Sumatera Islands based on surface observation data obtained in our group and satellite data. Water cycle in the maritime continent and the typhoon has been investigated using isotope observations of rain water. The modeling studies using both GCMs and RCMs have also been conducted on the local circulations, typhoon, as well as global circulations.

Our group also contributed to the Data Integration and Analysis System (DIAS) Project of the MEXT (Ministry of

Education, Culture, Sports, Science and Technology). We have collected various kinds of data related with water cycle in the Asian monsoon region and prepared for integration of these data. For isotope data, in particular, we developed the data-base system. We also constructed a gridded rainfall data set for Western Sumatera region based on integration of JEPP-HARIMAU radar and ground-based raingauge observations. We have analyzed the radar visibility using gridded elevation data, and then have derived a new relationship between radar reflectivity and rainfall intensity which is needed for making gridded integrated rainfall data.

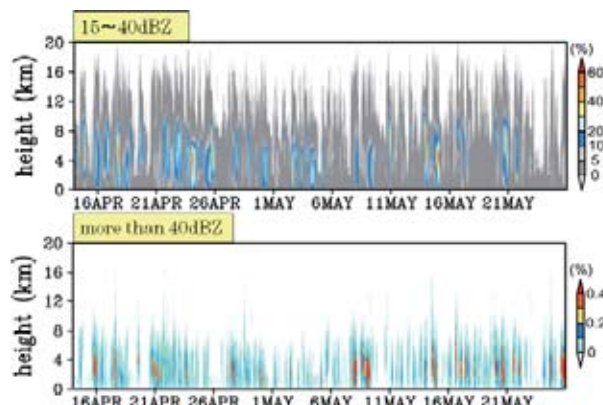


Fig.1 Height-time cross sections of dimension rate (%) in strong (upper panel) and relatively weak (lower panel) reflectivity obtained in the Dual X-band Doppler Radar intensive observation campaign in West Sumatera during April-May, 2007. Dimension of relatively weak reflectivity decreased from the middle of the observation period, on the other hand, that of strong reflectivity did not change or increased slightly in the latter half of the observation period.

Cold Region Hydrological Cycle Group

Observations at two sites in Eastern Siberia and one in Mongolia were maintained satisfactory in 2007/08. In Mongolia, drainage observation was enlarged and water sampling network for stable isotope was expanded. Also, snow/ice observation in western Mongolia and snow cover measurement were made corresponding to the IPY (International Polar Year). Model applied research using observation data, and analysis using satellite data were strongly advanced since it is the 4th year of the present 5 year Program. The main outcome is as follows.

- (1) Due to precipitation increase (rain, snow) since 2004, surface ground layer humidified, and soil temperature rose abruptly (which was stable since 1998) and active layer increased (Fig. 2), and it is considered that, as a result, melting of frozen ground in this region enhanced. Looking at the regional anomaly of meteorological elements, this change is considered as wide spread phenomena in Eastern Siberia. Such change affected land conditions, such as lake enlargement, discoloration of trees and others.
- (2) As a new observation method for area evaluation of sensi-

ble heat fluxes at 1-2 km scale, sinchirometer was applied at Yakutsk site.

(3) Land hydrological cycle model was developed, and seasonal variation of various regional distribution of hydrological cycle components such as active layer depth, soil moisture and others applying this model and in-situ data as forcing data (Fig.3).

(4) Evaluation of glacier shrinkage and in-situ observation of west Mongolian glaciers were started in 2007 (Fig.4). As a result, it was found that glacier area decreased 31% during the recent 50 years, and also ground observation showed that 2007/2008 year was a year of high negative mass balance.

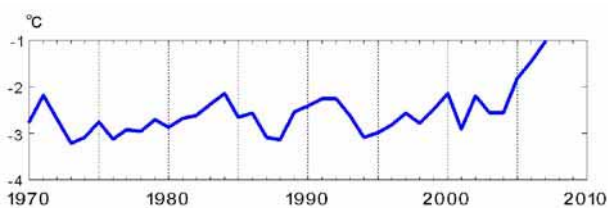


Fig. 2 Long-term variation of 3.2m depth annual mean ground temperature in Eastern Siberia. The shown value is the average value of three site (Verhoyansk, Pokorovsk, Tomot) with high quality data.

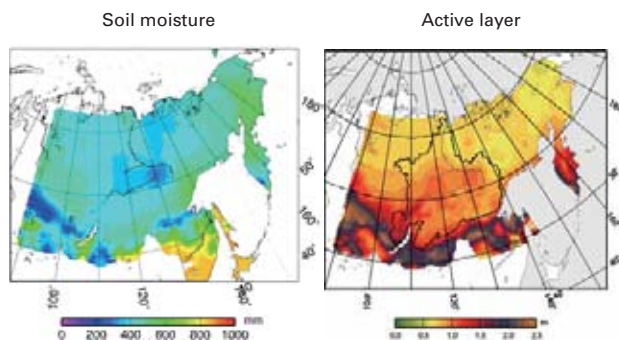


Fig. 3 Simulation result by land hydrological cycle model. The mean active layer depth for the period of 1986-2004(right), and soil moisture down to 3m depth for July 22, 2002(left) are shown.



Fig. 4 Photograph of Potanin Glacier below the Tavan Bogd Peak in Western Mongolia where in-situ observation was made in 2007. In the foreground, Automatic Meteorological Observation System which obtained full-year data is shown.

Atmospheric Convection Research Group

In order to summarize joint studies on mesoscale and large-scale precipitation phenomena in the Baiu frontal zone with Chinese researchers, the Japan-China Joint Workshop on Cloud and Precipitation was held at Yokohama in November, 2007. Future observation plans over the China were also discussed.

Long-range continuous observations with Doppler radar and ground-based measurement systems were executed to detect cloud systems and precipitation in the Palau areas. In Philippine, observations with automatic weather systems on surface were also continued.

The impact experiments were performed by adding dropsonde data obtained around the Palau area into the numerical model with reanalysis (ALERA). The result indicates the large positive impacts of winds and moisture are found over the downstream areas such as Japan Islands (Fig.5). This shows the close relationship between tropics and mid-latitudes.

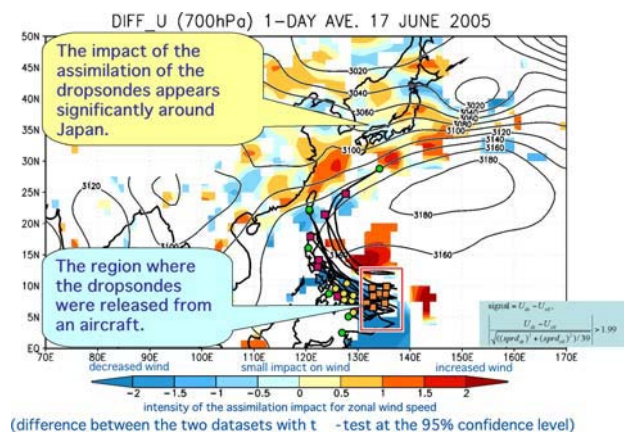


Fig. 5 Impact of horizontal winds at 700 hPa on the dropsonde data at PALAU2005. Reddish colors mean the high impact.

(3)Global Warming Observational Research Program

The goal of the observational research on the ocean and sea ice is to develop further insights into ocean structure and the carbon cycle which are related to global warming. This research is conducted in the Arctic Ocean, where variations in sea ice are considered to provide an indicator of global warming, and in the high latitudes of the Pacific Ocean where the biological productivity and the ocean uptake of CO_2 are high due to nutrient transport to ocean surface with the upwelling of deep-sea water. The paleoceanic environment is also examined by using marine sediment with the aim of reconstructing climatic changes that have occurred over the last few tens of thousands of years, in order to contribute to advancements in the prediction of changes in the global environment.

Arctic Ocean Climate System Group

Recent decline of Arctic sea ice is well known as one of the most remarkable evidences of global climate change, attracting public attentions, as well as scientists'. In particular, extent of Arctic summer sea ice in 2007 reached a record minimum ($\sim 4.1 \times 10^6 \text{ km}^2$), which is about $1.2 \times 10^6 \text{ km}^2$ lower than the previous record low in 2005. The acceleration of sea-ice decline and consequent change of the Arctic climate are evident. For example, the 2007 annual mean temperature was warmest in the Arctic region although global one in 2007 was not warmer than the record high. To track and understand ongoing changes of the Arctic Ocean, we have been conducting observational researches using research vessels, moorings and ice-drifting buoys. Especially in 2007, the first year of the International Polar Year (IPY), we could observe ocean and sea-ice conditions across the Arctic Ocean as IPY collaborations.

Such rapid sea-ice reduction in summer 2007 reminded us of the previous record minimum year. In 2005, as well as in 2007, we had very good opportunities to observe the Arctic sea-ice and ocean conditions. Based on the observation results in 2005 and the past, we examined both dynamical (sea-ice drift) and thermo-dynamical (sea-ice melting) effects on the decrease in the Arctic sea-ice. These results could be applied for clarifying the sea-ice decrease in summer 2007.

Ice drifting buoy observations since 2000 revealed that summer sea-ice export from the Arctic Ocean through the Fram Strait was large in 2005 (Fig. 1). Motivated by these observational results, we found that the significant decrease in sea ice extent in 2005 could be partly explained by the recorded-highest sea level pressure (SLP) gradient across the Transpolar Drift between 1979 and 2006 (Inoue and Kikuchi, 2006). The SLP gradient pattern regressed on the linear trends of ice extent was characterized by cyclonic circulation anomalies along the Eurasian coast, which tended to enhance the SLP gradient across the Transpolar Drift (Fig. 2). Due to the decreasing trend of SLP over eastern Eurasia, we hypothesized that 2005-like events will occur more frequently in the future. As we expected, the strongest SLP gradient across the Transpolar Drift was recorded in summer 2007, causing a record minimum of Arctic sea ice extent in September 2007 (Fig. 3). Therefore, our results (e.g., Inoue and Kikuchi, 2007) explained the decrease in the Arctic sea ice extent from a dynamical point of view.

Biogeochemical Cycles Group (including activity of Mutsu Institute for Oceanography)

a. Observational Studies in FY 2007

Biogeochemical Cycles Group and MIO Research Group conducted the time-series observation by moored instruments at

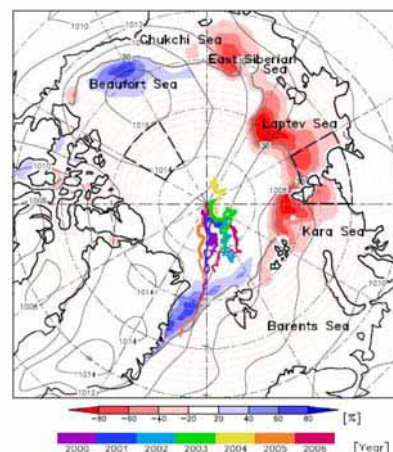


Fig. 1 Drifting trajectories for each year (thick line: May-September, thin line: October-December). Anomalies of sea-ice extent(%) in September 2005 relative to the previous 5-year average for September are superimposed as blue and red. The gray contour indicates 30% of the ice concentration in September 2005. The mean SLP from June to September in 2005 is denoted by black contours. Regions indicated by dashed lines were used to calculate the CL index shown in Fig. 3 (Inoue and Kikuchi, 2007)

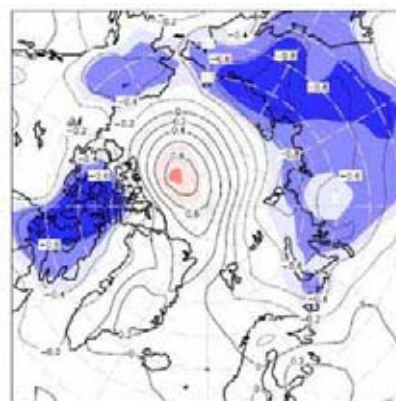


Fig. 2 Sea-level pressure in hPa regressed on a standardized yearly index of September Arctic sea ice extent. Light, medium, and heavy shadings indicate correlation coefficients exceeding the 90, 95, and 99 % confidence level, respectively. (Inoue and Kikuchi, 2007)

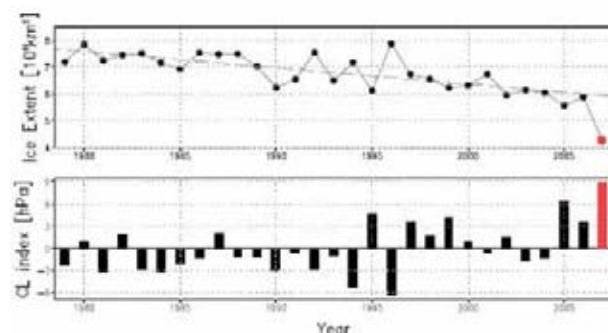


Fig. 3 Updated fig.s of Fig.3 used in a research paper of Inoue and Kikuchi (2007). Red colors show the data in September 2007 when the Arctic sea ice extent had a record-minimum value.

(upper) September sea ice extent obtained by summing the area covered by pixels that had 15 % or greater ice concentration (solid line) and its trend (dashed line).

(lower) SLP difference over the Canadian Basin and Laptev Sea are (CL index)

station K2 (47° N, 160° E) and shipboard observation around the K2 station in the northwestern North Pacific to obtain quantitative and mechanistic understanding of key processes of carbon cycle in the western subarctic Pacific.

Efforts were also made for development of an autonomous surface CO₂ partial pressure observing floats, with financial support by the Ministry of Education, Culture, Science and Technology (MEXT) as a part of Japan Earth Observation System Promotion Program.

b. Achievements

1) Distribution of nutrients and phytoplankton in the western subarctic Pacific during MR07-05

R/V Mirai cruise MR07-05 was conducted to study dynamics of nutrients and phytoplankton at the time-series station in autumn 2007. Concentration of nitrate plus nitrite at the surface seawater of Sta. K2 and its inventory in the upper 100m water column was 8 - 10 μ mole kg⁻¹ and 1.9 mol m⁻² during this cruise, respectively (Fig. 4). Primary productivity was measured twice during the cruise and valued 460 mg-C m⁻² day⁻¹ and 300 mg-C m⁻² day⁻¹ (Fig. 5). Those are typical values in the early autumn at Sta. K2.

Chlorophyll a concentration and phytoplankton community structure obtained during MR07-05 cruise were compared with those captured during MR05-04 in October, 2005 and MR06-03 in early summer, 2006 as shown in Fig. 6 and 7. In early summer, chlorophyll a concentration was over 1mg m⁻³ and diatom was predominant. However, haptophyceae was the most dominant phytoplankton taxa, and contributed to a half of total chlorophyll a concentration during this cruise. This result is consistent with a size distribution of phytoplankton.

2) Seasonal and interannual change of shallow carbonate chemistry and settling particle

Due to increasing input of anthropogenic carbon, biogeochemical cycle (carbon cycle) in the ocean can be affected and ocean acidification may be taking place. We have continued observations at the time-series stations K2 and KNOT (44° N, 155° E) to detect the seasonal and long term changes in the western subarctic Pacific.

Seasonal variability in normalized DIC (nDIC) and nitrate concentration at the sea surface in the Western Subarctic Gyre were from 81 to 113 μ mol kg⁻¹ and 12.7-15.7 μ mol kg⁻¹, respectively. Inventories of DIC and nitrate in the upper 100m water column showed maximum in March and the minimum in October. Based on the inventory change between March and October, seasonal new production was estimated to be 39 - 61 gC m⁻², about twice higher than that in the North Pacific subtropical gyre and the northeastern North Pacific (Kawakami et

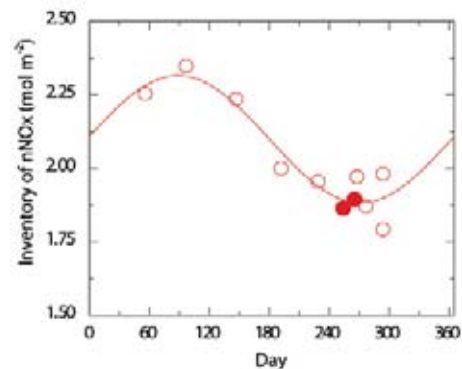


Fig. 4 Seasonal variation of water column inventory of nitrate and nitrite normalized to salinity 33 above 100m depth at Sta. K2.
● : Data obtained in 2007 cruise (MR07-05).
○ : Data obtained before 2007

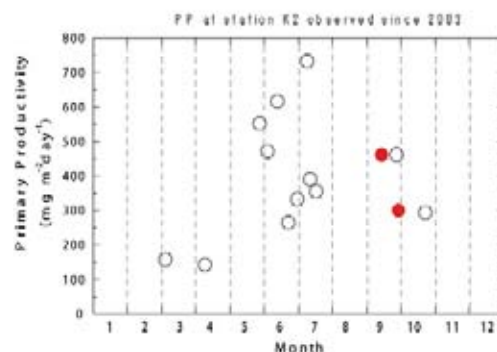


Fig. 5 Seasonal variation of primary production at Sta. K2.
● : Data obtained in 2007 cruise (MR07-05)
○ : Data obtained before 2007

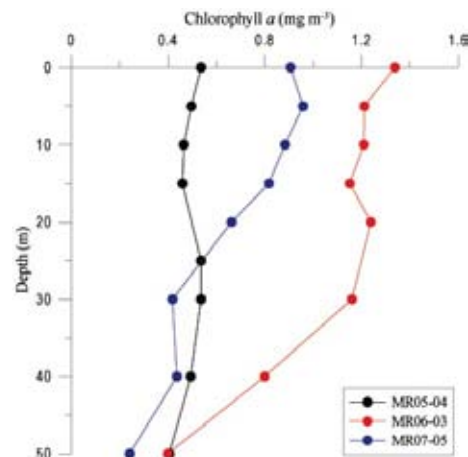


Fig. 6 Typical vertical distributions of chlorophyll a during MR05-04, MR06-03 and MR07-05 cruise.

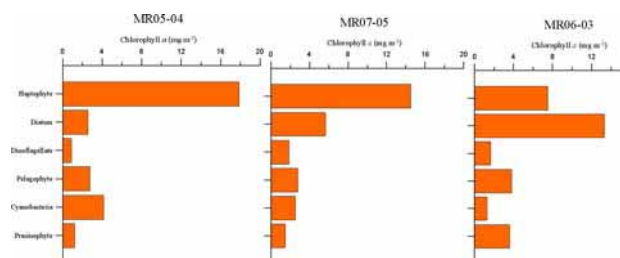


Fig. 7 Water column inventory of biomass in term of chlorophyll a obtained during MR05-04 cruise in October, 2005, MR07-05 cruise in September, 2007, and MR06-03 cruise from May to July, 2006.

al., 2007).

In the western subarctic gyre of northern North Pacific, it is found that dissolved inorganic carbon (DIC) concentration corrected for AOU and potential alkalinity variations, was increasing in the intermediate water (26.6-27.1 σ_θ , about 500m deep or shallower) as shown in Fig. 8. Data of DIC and carbonate system species were obtained from 1992 to 2007 at time-series stations K2 and KNOT. The increasing rates of the corrected DIC at those stations were 0.9 - 1.2 and 0.7 - 1.7 $\mu\text{mol kg}^{-1}\text{yr}^{-1}$ respectively during the last 15 years. Increasing rates near the surface were faster than those in the deeper layer. Around 2015, the corrected DIC contents in the surface layer would be almost equal to that in the subsurface layer (minimum temperature layer). In addition, CO_2 fugacity calculated from dissolved carbon and related species in the minimum temperature layer will also be smaller than that in the atmosphere after around 2020. These indicate that CO_2 will be absorbed by the ocean in the subarctic gyre even in wintertime. Namely, Western Subarctic Gyre will become a sink of CO_2 all year round by 2020.

MIO research group measured components of settling particles corrected by sediment traps deployed at K2 and found that the opal (biogenic silicate) to calcium carbonate ratio (Si/Ca) tends to decrease year by year as shown in Fig. 9. This trend might indicate biogeochemical cycle related with biomass and bioactivity is changing in the subarctic gyre, and this would be correlated with increasing DIC in the surface. Combined with the finding above mentioned, the function of biological pump in the region could be changed drastically after around 2020 when the CO_2 transport from air to the ocean is accelerated. Hence, the western subarctic Pacific deserves for prolonged observation to study variability of ecosystem structure and function and resulting biogeochemical cycle variability.

3) Development of an autonomous surface CO_2 partial pressure observing float

This float is a compact system capable of spectrophotometric pH analysis of CO_2 in sample seawater using a gas permeable membrane. The float developed in 2006 was tested in the equatorial area. It was attached on a side arm of TRITON buoy and moored at 2° N, 156° E (Fig. 10). The obtained data were similar to those obtained on R/V Mirai and in the range of CO_2 partial pressure around mooring spot (the equator to 5° N, 152° E to 160° E). The large variability seen in our data is likely caused by inhomogeneous of surface water mass and large diurnal temperature change near sea surface.

New float which is equipped with a solar panel is made in this year to double the operation duration. A picture of the new float is shown in Fig 11.

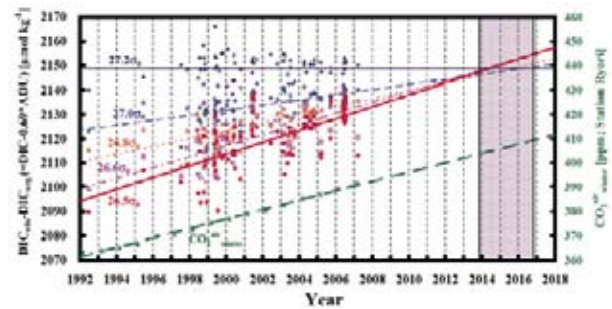


Fig. 8 Change of dissolved inorganic carbon contents on each isopycnal surfaces in Stations K2 and KNOT. Dissolved inorganic carbon contents are corrected for apparent oxygen utility to subtract decomposed organic carbon. Red, purple, orange, blue, dark blue dot: Corrected dissolved inorganic carbon on 26.5, 26.6, 26.8, 27.0, 27.2 σ_θ . Green line : CO_2 partial pressure in atmosphere (right axis)

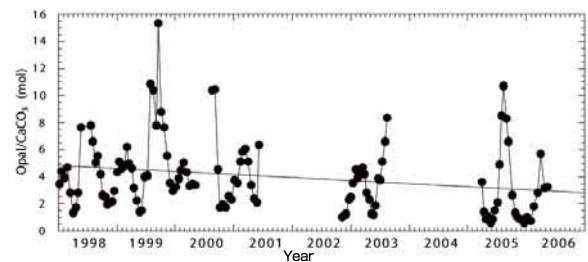


Fig. 9 Long-term trend in the ratio of biogenic opal to CaCO_3 trapped by a sediment trap at 5000m depth at K2.

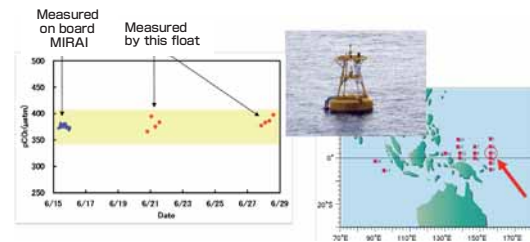


Fig. 10 Result obtained with Surface Ocean CO_2 Partial Pressure Measuring Float and its testing site

Left :

Result of observation

Red dots are the data obtained by this device. Blue are high-accuracy data obtained by R/V MIRAI a week before. Yellow belt is distribution range of CO_2 partial pressure obtained statistically around mooring spot (the equator to 5° N, 152° E to 160° E). (Aggregation of measurements since 1968).

Middle : Ocean CO_2 partial pressure observation device attached to TRITON buoy

Right : Map of mooring site(2°N, 156°E)



Fig. 11 New float equipped with a solar panel

a. Research activities in the field

To clarify changes in the Amur River discharge as related to changes in past Asian summer monsoon activity, we participated in a cruise of the R/V Khromov during August-September 2007 and collected sediment cores along the Sakhaline coast, inside the Russian exclusive economic zone (EEZ). We also participated in the Wakashio Maru cruise (one day in every month) and collected living planktic foraminifera to understand their ecology and to develop a new biological "thermometer" -a proxy for sea surface temperature (SST)-by using the Mg/Ca recorded in the planktic foraminiferal carbonate tests.

b. Research topic: Changes in intermediate-deep water circulation in high latitudes of the North Pacific associated with the B/Å warm event during the last deglaciation.

What will happen to the ocean environment in the near future as global warming progresses? We can learn the oceanographic responses to global warming from climate changes that occurred in the past during the deglaciation from 1.9 ka BP to 1.1 ka BP, across a millennial time scale without the influence of human activity.

We focused on the Heinrich 1 (H1) cold event (17.5-14.6 ka BP) and the Bølling/Ållerød (B/Å) warm event (14.6-12.9 ka BP). We reconstructed past ventilation changes in intermediate-deep water in the Okhotsk Sea (water depth, 1215 m; Fig.12), which is a source region for North Pacific Intermediate Water (NPIW), and off the Shimokita peninsula in the northwestern North Pacific (water depth, 1366 m; Fig.12), which is a downstream region of NPIW. We used ^{14}C age differences between coexisting benthic and planktic foraminifers from sediment cores to determine ventilation age (Fig.13). Because NPIW is considered to be an important temporal carbon reservoir, changes in its temperature and ventilation rate would change its carbon capacity.

In the waters off Shimokita, the ^{14}C age differences changed in response to the millennial time scale warm and cold events; differences were relatively small during the H1 cold period and large during the subsequent B/Å warm period [Ahagon et al., 2003] (Fig.13). In the Okhotsk Sea, we could not identify definite differences in ventilation ages corresponding to the H1 and B/Å events because of the sparse data due to poor preservation of foraminifer shells (Fig.13). However, slower ventilation during the last glacial maximum (LGM) was inferred from the older ventilation age in the Okhotsk Sea (Fig. 13), suggesting that the formation of Okhotsk Sea Intermediate Water (OSIW), which is an important source of NPIW, was reduced during the LGM [Okazaki et al., 2008]. One probable cause of the slow ventilation at intermediate depths in the

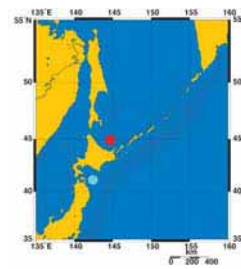


Fig.12 Sediment core sample locations. Red circle, Okhotsk Sea; blue circle, off Shimokita peninsula.

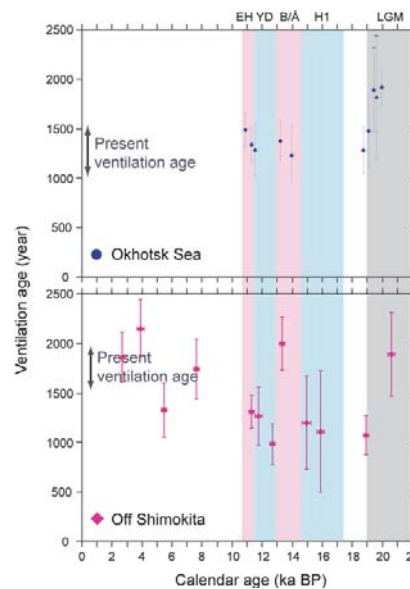


Fig. 13 Ventilation ages at intermediate depths (1000 m) in the Okhotsk Sea and off Shimokita peninsula. Pink fill, warm periods; gray fill, cold period. See text for explanation of abbreviations.

Okhotsk Sea is the reduced formation of dense shelf water (DSW) because of perennial sea-ice covering the source area of DSW in the Okhotsk Sea.

The Mg/Ca ratio in benthic foraminiferal shells, which is a proxy for bottom water temperatures, indicates that the bottom water temperature at a depth of 1366 m off Shimokita during the B/Å warm period was 2 to 3 °C higher than that during H1 (data not presented; Kimoto et al., 2008). Furthermore, a high CaCO_3 content was found simultaneously during the B/Å warm period in sediments from the Okhotsk Sea (data not presented), which is a source area of NPIW, implying that good carbonate preservation (deepening of the carbonate compensation depth) was caused by a warming and reduced ventilation rate of intermediate-deep water. It seems that the notable changes at the sea surface propagated rapidly to intermediate-deep water, and the temperature and ventilation age in intermediate-deep water and the carbon cycle changed in response to climate changes across the millennial time scale represented by the B/Å warm period.

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 Kimoto et al., 2008: Chikyu Monthly, 30(4), 182-188.
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(4) Ocean General Circulation Observational Research General Circulation Dynamics Group

We conducted hydrographic observations along 47° N and 179° E (WHP-P01 and P14) in the Pacific (Fig. 1) and obtained highly accurate data on temperature, salinity, dissolved oxygen, carbon items, chlorofluorocarbons and other materials.

We published a data book which includes data from hydrographic observation conducted from October, 2005 to January 2006 along 24° N (WHP-P02) in the Pacific.

Followings are revealed as the results of analysis of the data accumulated through the past observations;

- Heat content in the bottom layer on 47° N has increased since 1999.
- Warming and freshening in the middle to the upper layers of the South Pacific have continued since 1989.
- Water near the bottom of the Southwest Pacific Basin has significantly freshened.

The heat content change in deep layers of the entire Pacific is also estimated (Fig. 2).

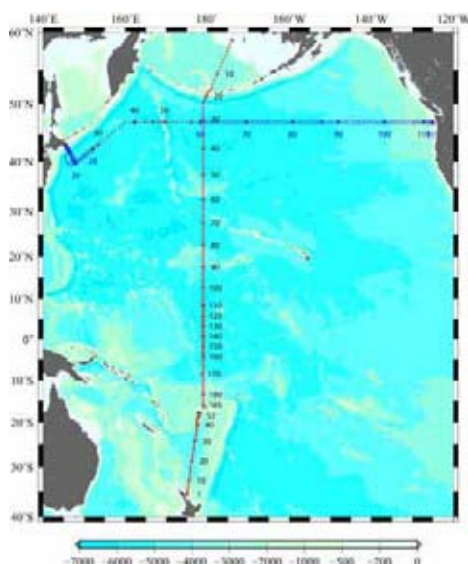


Fig. 1 Location of WHP-P1 (nominally 47°N) and P14 (nominally 179°E) stations

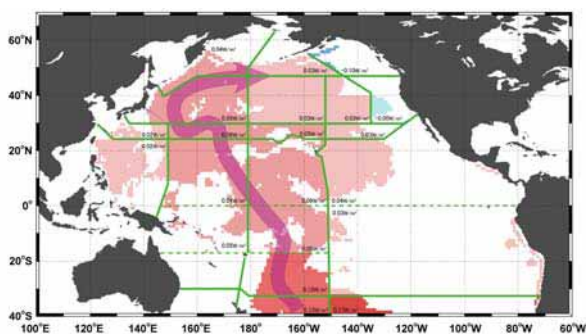


Fig. 2 Pathway of bottom water (purple arrow) and observation lines used for the estimation. Colored contours show the rates of change in heat content at the layers below the depth of 5,000m. Red and blue indicates increase and decrease of the heat content, respectively. Increase of the heat content in the bottom as a whole is revealed, and the increase is particularly significant along the pathway of bottom water.

Chemical Tracers Study Group

We analyzed 522 samples of carbon isotopes obtained along the observation line at 149° E (P10) and conducted quality-control of the analyzed data. Also, we analyzed about a half of 795 samples of carbon isotopes obtained along the observation line at 24° N (P03).

We examined data obtained by repeat hydrography cruises in individual basins, and found that accumulation of anthropogenic CO₂ was larger in the South Pacific and the South Indian.

We investigated apparent oxygen utilization (AOU) along the observation line at 47° N (P01), and found changes of AOU, which suggest decadal-scale cyclic changes in the entire subarctic region over the North Pacific.

We detected CFCs in the bottom layer of the ocean near the equator along the observation line at 179° E (P14). This suggests that northward speed of a Southern Ocean-origin bottom water is faster than previously estimated (Fig.3)

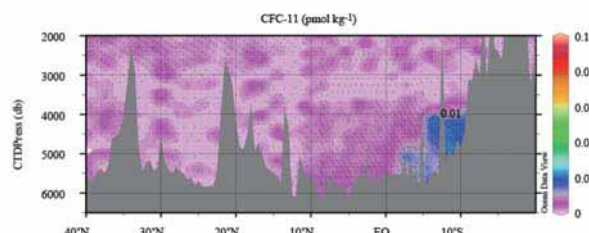


Fig. 3 Distributions of CFC-11 in the layers deeper than 2000 db along the observation line at 179°E. CFC was detected in the deep layer south of the equator (blue).

Kuroshio Transport and Surface Flux Group

Analyzing the data obtained by moored instruments observations from the fall of 2004 to the fall of 2006 in the Kuroshio and Kuroshio recirculation region south of Japan, time series of net amount of volume and heat transported by the Kuroshio were calculated. Data obtained by ship and moored instruments observations in 2005 and 2006 were made publicly available at the IORGC website.

The continuous observation of sea surface flux by surface mooring buoy (Fig. 4) to the north of Kuroshio Extension was maintained and its real-time data was made publicly available at the IORGC website.

Using a Voluntary Observation Ship running between Japan and Hawaii, measurements of water temperature, salinity and current velocity were conducted three times. The data of current velocities in the Kuroshio and Kuroshio Extension regions and of current velocity structure with oceanic eddies in the Subtropical Gyre region were obtained and its dataset was compiled.



Fig. 4 Sea surface mooring buoy (Height: 5 m from sea surface, Weight in air: 0.85 ton) at the sea surface flux observation site.

(5) Ocean, Land and Atmosphere Interactions Integrated Research

Utilizing observational data obtained by the atmospheric and oceanic field experiment- MISMO (Mirai Indian Ocean cruise for Study of the MJO-convection Onset) - in the boreal autumn of 2006, we obtained several results on the formation of the MJO. From the atmospheric data, it is shown that the moist process due to stepwise cloud-top development of cloud systems occurs and the Rossby wave may exist in the upper troposphere at the passage of the MJO. The characteristic features of oceanic mixed layer in the Indian Ocean Dipole were first found from the oceanic data such as strong salinity stratification and associated undercurrent. These results were reported at several international and domestic conferences such as IUGG.

In order to detect the seasonal variation of the MJO, the atmospheric field experiment with upper-air sounding, Doppler radar etc was conducted in the boreal spring of 2007 at the Maldives area.

Long-range continuous observations with Doppler radar and ground-based measurement systems were executed to detect intraseasonal and interannual atmospheric variations over the western Pacific Ocean.

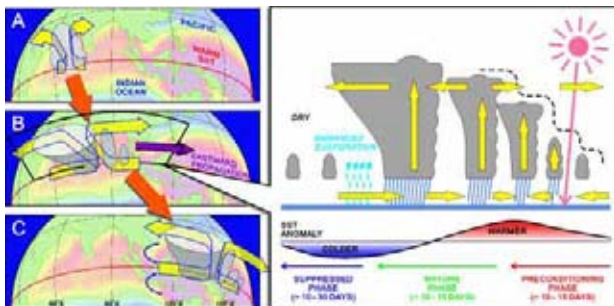


Fig.(Left) Schematic fig.s of temporal variation of eastward-propagating large-scale cloud systems (=MJO) and inner atmospheric circulation. (Right) East-west - height section of stepwise cloud-top development of cloud systems under the atmospheric environment and surface sea temperature (SST) at the passage of the MJO.

1.1.2 Global environmental prediction research

(1) Climate Variations Research Program

Climate Variations Research Program (CVRP) studies climate variations of time scale that extends from seasons to decades and related to oceanic phenomena in the Asia-Pacific sector including the Indian Ocean, polar and sub-polar oceans. To understand fundamental processes involved in climate variations, our research is conducted using oceanic and atmospheric models of various degrees of freedom as well as various analysis methods. We also conduct predictability and social application studies on the influence of the global climate variability upon regional atmospheric and oceanic phenomena. The study on climate variations is now becoming a new norm of investigations where the traditional basic sciences meet the urgent need of the environmental or social problems. Our cutting edge studies on the Indian Ocean Dipole (IOD) as a basic science has a variety of potential applications to the global and regional human activities and our active involvement in the regional hydrological cycle study of the former Kyosei project is such an interdisciplinary effort as a precursor of much larger activities of utilizing climate prediction information for the benefit of our social activities.

Another important strategic element of pursuing the above goals of our research is the effective use of the Earth Simulator (ES). Now state-of-the-art coupled GCMs have become inevitable research tools for climate variations studies and their physical and computational performances are quite important factors for the success of our project studies. Since any model cannot be perfect and to develop a high-performance GCM is a time-consuming task, we decided to take multi-models strategy to use them in collaborative frameworks of research. The collaboration with an EU research group of SINTEX (Scale interaction experiments in climate simulations) project to develop further the original goal of SINTEX by optimizing their GCM codes for ES and to use it for our research purposes turned out to be a quite fruitful research strategy which led to our landmark event of the success of IOD prediction for the first time in the world.

Research Results

a. SINTEX-F Climate variability Prediction Experiments

We have shown, using results from a 200-year hindcast experiment of SINTEX-F coupled general circulation model (CGCM), that the model demonstrated significantly high performance in reproducing El Niño/Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD) phenomena, which are the two major climate modes in the tropical oceans that affect the global climate conditions. In addition, our climate prediction experiments have successfully predicted the IOD event appeared during boreal summer and fall in 2006 for the first time in the world. Associated with this 2006 positive IOD event, severe droughts occurred in the eastern rim regions of the Indian Ocean, such as Indonesia and Australia. On the other hand, the east African countries were suffered by devastating floods, by which more than half a million people had forced to evacuate from their home lands. Successful forecasts of such significant climate mode in the Indian Ocean with the lead-time of about half a year clearly suggest that the IOD predictability study enters a new phase. In this fiscal year, we continued the predictability studies on short-term climate variability and conducted detailed analyses on various processes in the atmosphere and oceans, which would have potential influences on the predictability in the coupled climate prediction models.

IOD usually begins with negative sea surface temperature anomaly (SSTA) along the southern coast of Sumatra-Java islands and associated southeasterly wind anomaly over this region during late spring and early summer. In the case of 2006 positive event, subsurface negative temperature anomaly in the eastern tropical Indian Ocean appeared prior to the IOD event. It is found that this precondition was generated by the propagation of the upwelling Rossby waves in the southwestern Indian



Fig.1 Horizontal distribution of anomalies in the 20°C isotherm depth (D20) averaged over Nov. 2005 and Jan. 2006. It clearly demonstrates that there is a large area of the negative D20 anomaly in the western Indian Ocean, with the maximum in the southern hemisphere.

Ocean around Nov. 2005, more than 9 months before the appearance of the IOD event (Fig.1), and subsequent eastward propagation of the upwelling Kelvin waves along the equator, showing the importance of the ocean dynamics for the IOD predictability.

In 2007, the positive IOD event occurred again in the tropical Indian Ocean, generating the first consecutive positive IOD years ever since early 1950's, when the recent comprehensive observations started to take place. At the same time, La Nina phenomenon appeared in the Pacific Ocean, which provided quite rare condition with positive IOD in the Indian Ocean, 40 years after the previous event of the same situations in the tropical Indo-Pacific sector in 1967.

Figure2 indicates horizontal distribution of the SSTA averaged over three months during Sep. to Nov. 2007, predicted from Apr. 2007 as the initial condition for the SINTEX-F CGCM forecast experiment. The typical SSTA pattern of the positive IOD event can be seen in the tropical Indian Ocean, while the eastern equatorial Pacific demonstrate large negative SSTA associated with strong La Nina event. Successful prediction of the both climate events in the two basins suggests the significant performance of SINTEX-F model in reproducing not only the climate modes themselves but also the climatological seasonal cycle as basic states for these climate modes.

Most of the results were published in major scientific journals, and the press release on the 2007 IOD prediction caught strong attention of public. We will continue the study on the processes affecting the ENSO/IOD predictability and will try to enhance our contribution to disaster prevention activities in the regions surrounding the Indian Ocean, through improving the prediction skills of the short-term climate variability over Indo-Pacific sector.

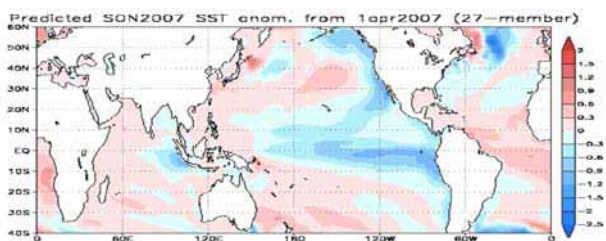


Fig.2 Predicted sea surface temperature anomaly (SSTA) during Sep./Oct./Nov. 2007, starting from Apr. 1st, 2007. Typical SSTA patterns of the positive IOD event and La Nina phenomenon can be seen in the tropical Indian Ocean and Pacific Ocean, respectively.

b. Studies on oceanic variability based on the OFES simulation

Collaborating with the Earth Simulator Center, we have conducted very high resolution ocean simulations using the Ocean GCM for the Earth Simulator (OFES). Those are highly valuable to improve our understanding of various spatio-temporal oceanic variations not only in the surface layer, which interact with the atmosphere directly, but also those in the sub-surface ocean interiors. In our program, we investigate oceanic variability from extensive viewpoints: behaviors of eddies, their impacts on large-scale ocean circulation, global ocean energy balance, and so on. Meanwhile, here a particular study on decadal variability in the Pacific Ocean is reported.

For decadal variability in the tropical Pacific Ocean, many hypotheses have been proposed. One of them suggests that oceanic temperature anomalies subduct into the subsurface layer in the subtropics, move equatorward, and surface there to induce equatorial SST anomalies. For the North Pacific Ocean, this has been denied. On the contrary, in the South Pacific, such equatorward temperature anomaly propagation has been found in observation, ocean GCMs, and a coupled GCM. Interestingly, cool (warm) subsurface temperature anomalies tend to be formed when SSTs have warm (cool) anomalies; their formation mechanism is not intuitive and was not understood. While importance of diapycnal mixing at the bottom of the surface mixed layer was suggested recently, Nonaka and Sasaki (2007, J. Climate) gave a simple explanation for this counter-intuitive temperature anomaly formation by paying attention to large meridional migration of outcrop line of isopycnal surfaces along which the temperature anomalies subduct.

Figure3 shows that subsurface temperature anomalies propagate from the southeastern subtropical South Pacific to the western boundary region (panel b), and further extend to the equatorial region (panel a). On the one hand, in the formation region of the anomalies, warm (cool) anomalies tend to be formed (panels b and c) when the latitudes where the isopycnal surface that the anomalies subduct intersects with the sea surface migrates equatorward (poleward), as warm (cool) water exists in lower latitudes. On the other hand, the outcrop latitudes tend to migrate equatorward (poleward)

when sea surface water in the region has cool and dense (warm and light) anomalies. As a result, when SST is cool (warm), warm (cool) anomalies are formed on the subsurface isopycnal layer. Further, as SSTs in the eastern equatorial and in the eastern South Pacific subtropics have positive correlation (panel d), warm SST anomalies in the eastern equatorial Pacific can induce warm and cool temperature anomalies in surface and subsurface layers, respectively, in the eastern subtropical South Pacific. The induced cool anomalies propagate equatorial region taking more than five years. If these anomalies can further induce cool anomalies in the equatorial region, warm temperature anomalies would be formed in the subtropical South Pacific, and a closed cycle with a decadal time scale might be induced.

Although the equatorial decadal variations have been suggested to have influences on different time scale phenomena, for example, interannual variations such as El Niño-Southern Oscillation by modifying their background field, still it has not been understood adequately, mainly due to paucity of long-term observations. Using outputs of the OFES hindcast simulation enables us to investigate decadal and various time-scale oceanic variations with high spatio-temporal resolutions for sufficiently long term. The OFES output is, thus, noticed from worldwide ocean research community, and expected to be supplied continuously.

c. Climate variations in the extra-tropical and polar regions

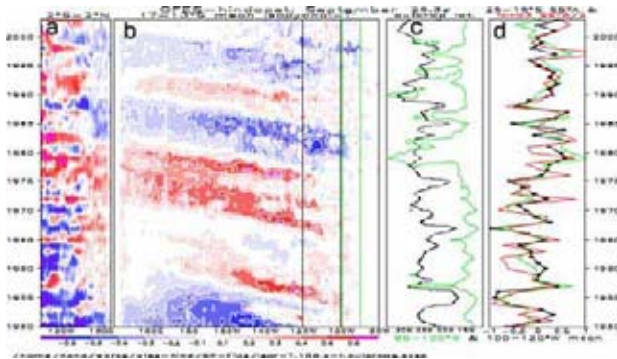


Fig.3 (a, b) Longitude-time sections of temperature anomalies on the 1025.3 kgm⁻³ isopycnal surface averaged between (a) 2°N-2°S and (b) 17°-13°S. The longitude axis is reversed and compressed in (a). (c) Time series of latitude of intersection of the isopycnal and sea surfaces. (d) Sea surface temperature anomalies averaged in 15°-25°S (black and green) and 4°N-4°S, 90°-150°W (red, reduced by a factor of 0.5). In (c) and (d), black (green) curve presents an average between 120°-100°W (100°-90°W).

We computed the near-surface baroclinicity for the atmosphere, using the monthly mean ERA40 reanalyses products, and calculated the empirical orthogonal functions (EOFs) of the field for each month in the regions of two major northern hemispheric storm tracks, one in the North Atlantic basin and the other in the North Pacific. From this diagnosis, we found roughly two types of variability in the near-surface baroclinicity in the vicinity of the storm tracks. One is a pattern characterized by a meridional shift in the areas of large near-surface baroclinicity along the Gulf Stream and Kuroshio/Oyashio, while the other is characterized by a change in the strength of the near-surface baroclinicity in these areas. These two patterns are observed fairly clearly in the North Atlantic storm track in cold months, whereas they are not so clearly visible in the North Pacific storm track. However, while the North Atlantic storm track does not exhibit any clear pattern of variability in warm months, the North Pacific storm track shows very clear patterns of meridional shift in the summer. From anomaly composites of various atmospheric fields, sea surface temperature (SST), and the net surface heat flux that accompany the dominant anomaly patterns in the near-surface baroclinicity, we found cases in which variations in the path of and/or heat transport by the Gulf Stream and Kuroshio/Oyashio are most likely forcing major large-scale atmospheric anomalies throughout the troposphere and lower stratosphere (Fig.4).

These cases are found in cold months, December - April,

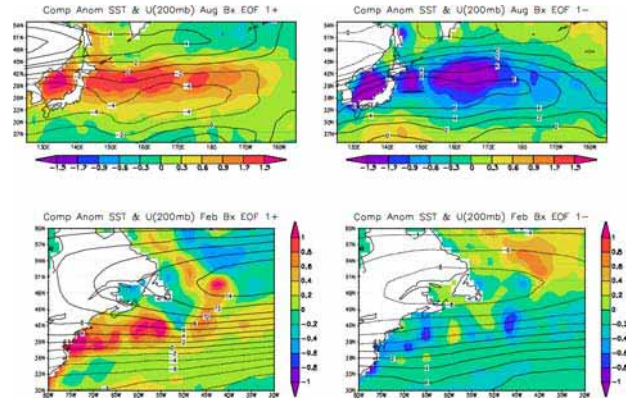


Fig.4 Composites of anomalous SST (degree C, color) and zonal wind (meters per second, contours) at 200hPa (about 10km above the sea level). Upper panels: The positive (left) and negative (right) phases of the first EOF in August found for the North Pacific storm track. Lower panels: The positive (left) and negative (right) phases of the first EOF in February found for the North Atlantic storm track.

along the Gulf Stream, and in July and August along the Kuroshio/Oyashio. An important point to note is that major variations in the Gulf Stream or Kuroshio/Oyashio do not necessarily generate significant atmospheric anomalies, since their impact on the near-surface baroclinicity may be canceled by the land surface temperature anomalies or dwarfed by baroclinic anomalies associated with the land surface temperature anomalies. Their impact on the near-surface baroclinicity may be ignored by the large-scale atmospheric motions when the jet flows away from the area of baroclinic anomalies also. These factors make it difficult to detect the impact of extratropical SST anomalies on the large-scale atmospheric state when the data are analyzed with the SST in focus. We will be extending this research by examining the atmospheric response to SST anomalies in the vicinity of the Kuroshio/Oyashio in the summer, using a regional atmospheric simulation model at a very high spatial resolution required to resolve narrow bands of SST anomalies along the oceanic fronts.

Interannual variability of the East Asian winter monsoon exerts significant influence on weather conditions over Japan, including severe cold waves in the 2005/6 winter and anomalous mildness in the 2004/5 winter. We have been investigating the causes and predictability of the monsoon variability, focusing on the remote influence of the tropical variability and anomalous sea ice cover in the Arctic. It is suggested though our experiments with an atmospheric general circulation model (AFES) on the Earth Simulator that below-normal sea ice cover within the Barents/Kara Seas in late autumn may possibly lead to above-normal intensity of the wintertime Siberian High. Furthermore, we have identified a stationary tropospheric wave train in late winter over the Eurasian continent as a precursory signal of a midwinter surface pressure anomaly similar to the Arctic Oscillation (AO). The wave train modifies the upward propagation of the climatological planetary waves, leading to the formation of an AO-like anomaly in the stratosphere and its subsequent extension down to the surface. These are significant findings that can be key factors for seasonal forecast of winter-time weather over the Far East.

Deeper understanding of the decadal climate variability inherent to the midlatitude North Pacific that accompanies the

anomalous Aleutian Low requires our deeper understanding of the ocean-to-atmosphere feedback in the subpolar oceanic frontal zone. We have found through our analysis of an eddy-resolving OFES hindcast integration that cool SST anomalies that form off the Hokkaido Island along the strengthened Oyashio tend to extend eastward along the subpolar front in cooling the overlying atmosphere. This tendency indicates that SST anomalies generated through such oceanic processes as advective effect of the Oyashio and equatorward displacement of the subpolar front can exert thermal forcing on the atmosphere. In order to further explore the characteristic nature of air-sea interaction in a midlatitude oceanic frontal zone, we analyze an output of a high-resolution CGCM (CFES) on the Earth Simulator. With its eddy-permitting ocean component, CFES can represent a well-defined oceanic front on the warmer flank of the strong Antarctic Circumpolar Current. Tight surface air temperature (SAT) gradient that is maintained across the prominent SST front energizes individual cyclones and anticyclones to anchor the core of the Southern Hemisphere storm track where the surface westerlies are particularly strong due to poleward eddy heat transport. Our analysis reveals (Fig.5) that on the warmer side of the SST front a huge amount of heat is released from the ocean into cold air behind a cold front while on the cooler side of the SST front the ocean cools off warm air behind a warm front. After relaxed by poleward heat transport by atmospheric disturbances, SAT gradient across the

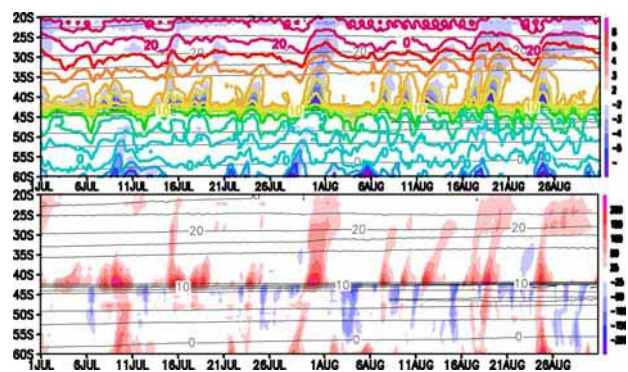


Fig.5 Air-sea interaction characteristic of the oceanic frontal zone in the South Indian Ocean reproduced in a high-resolution coupled ocean-atmosphere GCM (CFES). Latitude-time section for 55°E from July to September of the first year. (upper) Surface air temperature (SAT; contoured for every 2 degs.) and SST-SAT (colored as indicated on the right; bright colors for positive values). (lower) SST (contoured for every 2 degs.) and sensible heat flux from the ocean surface (colored as indicated on the right; bright colors for upward flux)

SST front is restored effectively with the cross-frontal differential heat supply from the ocean to allow the recurrent development of the disturbances. This is a newly found aspect of the air-sea interaction characteristic of midlatitude oceanic frontal zones.

d. JCOPE-related researches

JCOPE group has been developing a high-resolution, real-time prediction system for multi-purpose application researches as well as for the basic understanding of the variation mechanism of the Kuroshio. Since the active social contributions through developed technologies is one of our important goals of our project, now we are promoting a couple of activities aiming at that goal: the one is a cutting edge model developing effort (starting from FY 2005) of coupling oceanic currents with wind waves and the other is the further advancement of our ocean routing support system initiated from FY 2006. In addition to those, using our developed system, we are also doing application researches on the problems of fishery resource control and prediction, which was collaborative activities with Fishery Research Agency (FRA) under the research themes of "developing an advanced Japan coastal ocean prediction system and coupling with fishery ecosystem (from FY 2007 to 2010)" and "developing tuna resource control method (from FY 2007 to 2008)". The latter research is a joint effort with FRA and Japan Fishery Information Service Center.

In our leading edge research on developing a wind-wave model, we succeeded in estimating the coupling effect of oceanic currents on wind-wave spectral by improving nonlinear energy transfer function (Fig.6), which was published in JPO. Methods of observational validations of the model were also studied.

As to JCOPE2 for oceanic ship routine support system, we performed parameter-tunings in data assimilation systems by utilizing in situ data. As model performance improving efforts, we modified a pressure gradient estimating scheme and also upgraded advection and diffusion schemes. In addition, the Yangtze-river run-off effect and tidal mixing effects in the coastal oceans are introduced in our model and further nesting systems connecting the present model with horizontal resolu-

tion of 1/12 deg with finer ones with 1/36 and 1/108 deg are developed. The research outcomes mentioned above have been transferred to our ocean routing support system through oceanic prediction venture. In crude oil tanker routings, a remarkable reduction of fuel was achieved by utilizing our prediction data. (newspaper article in Fig.7) Based on this achievement, JCOPE group was awarded a JAMSTEC prize for outstanding social contributions.

e. Researches on geophysical fluid dynamics

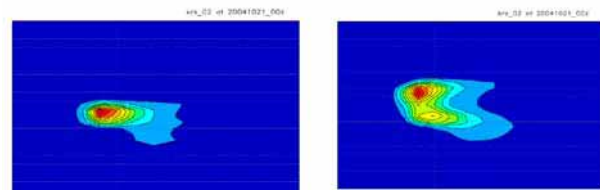


Fig.6 Wind-wave spectrum in a coastal sea test region reproduced by high-resolution current-wave coupled model. (Left: no current, Right: with current)



Fig.7 Article on ship routings. From Nihon-Keizai Shinbun.

Through Aiki and Yamagata (2006) and Jacobson and Aiki (2006), we proposed a theory that explains consistent roles played by such diversified phenomena in ocean dynamics as wind stress, Ekman transport, baroclinic eddies and eddy-induced drag from a view point of the momentum and energy budget. Analyzing high-resolution OFES data, we showed that the theory is valid for oceanic circulations in the world oceans and, especially for the circumpolar currents dynamics, our theory solved the inconsistency problem so far remained untouched and was published in (Aiki and Richards, 2008). Although the energy budget on the global ocean circulations is actively

discussed in the field of internal gravity wave research, our work gives the first quantitative estimate on the energy conversion rate due to meso-scale eddies using the global high-resolution simulation data and it contributes to those two fields complementary. Our theory turned out to be consistent with a theory on semi-Lagrange mean developed in dynamical meteorology and further researches on comparison are to be done.

f. International collaboration

At the end of last year, we hosted an international symposium on climate variations and predictability studies and strengthened international collaborations especially in the field of predictability experiments using SINTEX-F1 coupled model. Since SINTEX-F1 outperforms other leading models in ENSO and IOD predictions, we received prediction data release requests from JMA, MRI, GFDL and other institutes in NOAA, University of Hawaii, Seoul National University, CSIRO, University of Tasmania, Met Office of Malaysia, ECMWF, Ocean University of Qingdao, Institute of Atmospheric Physics of CAS and IMD and others in addition to our participation in multi-model ensemble experiments at APCC. Our multi-faceted international collaborative activities include those data release activities.

g. Social contributions

As a noteworthy social contribution relating to JCOPE activity, Nihon-Yusen, Inc.: one of the big global shipping companies, started to use our data as a new component of its ocean routing support system. This data provision service is done through a newly established LLP on oceanic currents as the first venture business of JAMSTEC. A new research on a possible cause of severe winter conditions in Japan induced by the decrease of the Arctic sea ice was spotlighting by mass media. Extraordinary heavy snowfall in China may be occurred by this cause. We also initiated a new collaborative MAFF funded research with ESC aiming at the evaluation of possible large outbreak of marine organisms associated with the surrounding environmental changes. In addition, four members of our program joined JMA task force of investigative commission on unusual weather.

(2) Hydrological Cycle Research Program

Research Results

Our program conducts researches on understanding the dynamics of hydro-climate and hydrological cycle and their variabilities, particularly over the Eurasian continent and the Asian monsoon region, based on the comprehensive data, including those from international projects (e.g., GEWEX/GAME, CEOP/CAMP), in-situ observational data by Institute of Observational Research for Global Change (IORGC), various kind of satellite data, and objectively-analyzed global data. The outputs from GCMs and RCMs are also used both for further understanding and for model validations. Based on these knowledges, we also develop and improve hydrological cycle models from basin or region-scale up to global-scales.

To understand and model hydro-meteorological processes in Asian region using high-resolution observational data, cooperative studies on the Yellow River basin hydro-meteorology was conducted with the Research Institute for Humanity and Nature (RIHN), and on cloud-precipitation system in East Asia with the Ocean Research Institute (ORI) of University of Tokyo and Meteorological Research Institute (MRI). A cooperative study with the Atmospheric Composition Research Program of FRCGC was also conducted for improving the cloud-radiation model for satellite-remote sensing of air-pollutants. Model accuracies were also confirmed by mutual comparison of the models. To upgrade the radiation transfer model for vegetation canopy system, a cooperative study with the Ecosystem Change Research Program of FRCGC was conducted. To improve model for meso-convective systems for GCMs, a cooperative study with the Global Warming Research Program was also conducted.

In addition, to contribute in improving prediction of hydrological cycles associated with the "global warming" for future, we have made validation of variability and changes of hydrological cycles simulated for the past several decades in the high-resolution GCMs of CCSR/NIES/FRCGC and of JMA/MRI with those from the observations particularly for Eurasia-Pacific and Asian monsoon regions, to examine systematic errors of the models, as well as analysis of the results from

global warming experiments for the next 100 years.

The groups for large-scale hydrological processes (group 1) and land-surface hydrological processes (group 2) conducted analyses of hydrological processes in high-resolution GCM outputs computed by the Earth-Simulator, in cooperation with the former K-1 and K-4 projects. Simulations by regional climate models (RCMs) and CReSS (cloud-resolving storm simulator) were made mainly using the Earth Simulator.

From fiscal year 2006, a modeling study project on "quantitative assessment and prediction for change of Asian monsoon climate induced by human activities" has started supported by the global change research program of the Ministry of the Environment. HCRP is in charge of the sub-group of this project on the impact of land cover/land use changes, and has started some preliminary experiments.

The details of the research activity are reported in the following chapters.

a. Large-scale Hydrological Cycle Processes Group

a-1. The relationship between summer Arctic sea ice and summer atmospheric circulation

Interrelationships between year-to-year variations in September Arctic sea ice extent and summer sea level pressure and surface air temperature at high northern latitudes are examined making use of microwave satellite imagery and atmospheric data for the period 1979-2006 (Ogi and Wallace, 2007). In the time series of September sea ice extent, the trend accounts for nearly half the variance. Summertime surface air temperatures averaged over the polar cap region have warmed by $\sim 1.2^{\circ}\text{C}$ since 1979 and year-to-year variations in summer sea-ice extent are correlated with variations in surface air temperature (Fig.1).

Years with low September sea ice extent tend to be characterized by anticyclonic circulation anomalies over the Arctic, with easterly wind anomalies over the marginal seas where the year-to-year variability of sea ice concentration is largest. It is hypothesized that the summer circulation anomalies cause sea ice extent principally by way of the Ekman drift in the marginal seas. However, the pattern associated with the linear trend is somewhat larger in horizontal scale. The pattern of the SLP

trend implies a trend in the surface wind vector directed from the Chukchi Sea toward the Fram Strait and a more cyclonic flow with increased Ekman divergence of sea ice over all but the Canadian sector of the Arctic (Fig.2)

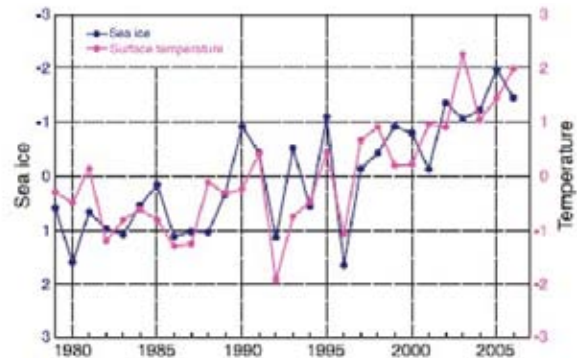


Fig.1 Standardized yearly index of September Arctic sea ice extent (inverted, indicated by the blue curve, scale at left) and summer (mean of July, August and September) air temperature anomalies averaged over the area poleward of 60°N at 2 m (red curve, scale at right)

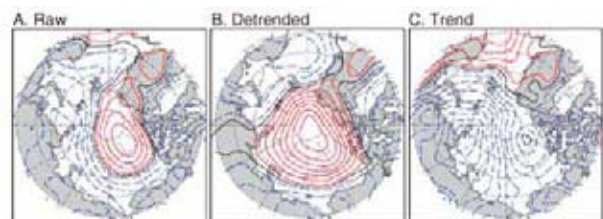


Fig.2 (a) Summer (July-August-September) sea-level pressure regressed on an inverted standardized yearly index by September Arctic sea ice extent. (b) As in (a) but based on the inverted detrended index. (c) The linear trend, in unit of hPa per decade. The red lines are positive anomalies. Contour interval, 1 hPa.

a-2. Decreasing Trend in Rainfall over Indochina during the Late Summer Monsoon: Impact of Tropical Cyclones

We examined the decreasing trend in rainfall during the late summer monsoon season (September) in Thailand from 1951 to 2000 and associated changes in tropical cyclone (TC) activity. Thailand receives significant rainfall from May to October and experiences two rainy peaks in late May to early June and in September. A previous study reported a decreasing trend in September rainfall in Thailand and, based on a regional climate model, suggested that the trend was associated with local deforestation. However, the long-term trend may also be affected by changes in large-scale circulation. Thus, the purpose of this study was to investigate changes in large-scale circulation associated with the decreasing rainfall trend.

Westward-propagating TCs from the South China Sea and

the western North Pacific brought most of the rainfall over Thailand in September. TCs include tropical depressions, tropical storms, severe tropical storms, typhoons, and residual lows. 70% of the rainfall amount in September was estimated to be associated with TCs.

The 50-year time-series of September rainfall over Thailand showed a significant decreasing trend. TC activity defined by 700-hPa relative vorticity, showed a weakening trend over the Indochina Peninsula (Fig.3). TC tracks also suggested the weakening of TC activity over this area. The long-term trend in rainfall during the late summer monsoon season was closely associated with changes in TC activity over the Indochina Peninsula; these changes were likely caused by changes in the major course of TCs (Fig.3). Concurrent with the changes in TC tracks, there was a change in the TC steering current around the Philippines archipelago and Taiwan. This led to the TC activity over the Indochina Peninsula being inactive, probably resulting in the long-term decrease in rainfall over Thailand. (Takahashi and Yasunari, 2008, JMSJ)

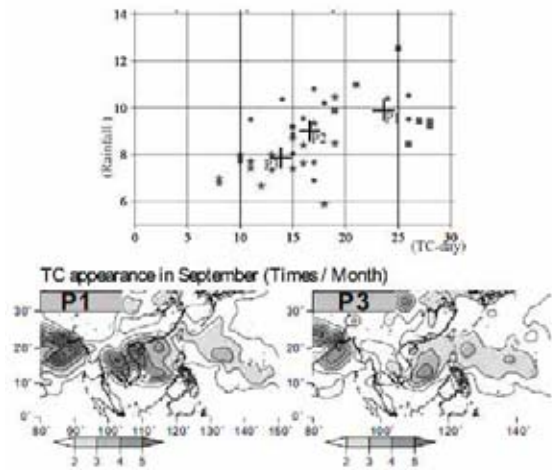


Fig.3 (upper panel) Scatterplot between September rainfall over Thailand and TC day defined by 700-hPa relative vorticity. Rectangle, circle, and star symbols indicate the relationship in each year during P1 (1958-65), P2 (1966-80), and P3 (1981-95), respectively. The crosses labeled P1, P2, and P3 show the mean relationship of each period. (lower panel) Distribution of TC-appearance frequencies during P1 (1958-1965) and P3 (1981-95). Unit is times per month.

a-3. Evaluation of impacts of land cover/use change by cultivation in pre-industrial period on Asian monsoon climate

Impacts of Land cover/use change by cultivation on Asian monsoon climate in the pre-industrial period, 1700-1850, was

investigated by AGCM using the global vegetation maps since 1700 (Ramankutty and Foley, 1999; Hirabayashi et al., 2005). In 1700-1850, impacts of human-induced increases in greenhouse gases and aerosols were negligible. Therefore cultivation was the major anthropogenic disturbance to the climate in that period. The cultivated areas in Asia for 1700-1850 were the Indian subcontinent and China. Surface albedo was increased and surface roughness was decreased due to land cover/use change, leading to changes in evaporation and water vapor convergence in those regions. As a result, monsoon precipitation was reduced in those regions, particularly in the Indian subcontinent, from 1700 to 1850 (Fig.4). This result is consistent with the estimation of long-term changes in Indian monsoon precipitation by Himalayan glacier ice-cores. (Takata et al., PNAS, to be submitted)

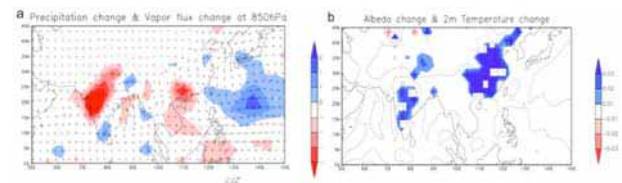


Fig.4 June-August mean changes from 1700 to 1850. a) Precipitation (shades in mm/day) and water vapor flux at 850 hPa (unit vector in 2/s). b) Albedo (shades) and surface air temperature at 2 m (contours in K).

b. Land-Surface Hydrological Cycle Process Group

b-1. Examination of the water budget in the Yellow River basin

In this study, we describe a hydrological model that considers five categories of land use. Calibration and verification of the model were carried out at two independent watersheds (Tangnaihai, 120,000 km² and Lushi, 6,400 km²). The model results represent the hydrographs and annual runoffs at two gauge stations over a relatively long-term period (18 years at Tangnaihai and 21 years at Lushi). The Nash-Sutcliffe efficiency coefficients for monthly discharge were 0.87 at Tangnaihai for the period of 1980-1997 and 0.84 at Lushi for the period of 1980-2000. The model was applied to other watersheds of the Yellow River basin above Huayuankou station, and water budget components in each region were analyzed. Water use for agricultural irrigation was stable throughout the entire simulation period. A numerical experiment of water conservation for the whole basin above Huayuankou station demonstrat-

ed that if the number of irrigation days was reduced by 20%, 40% or 60%, water use could be reduced by 26.6% ($54.6 \times 10^8 \text{ m}^3$ in volume), 52.1% ($106.9 \times 10^8 \text{ m}^3$), or 80.7% ($165.6 \times 10^8 \text{ m}^3$) compared to the current situation.

b-2. Modeling of water budget in a deciduous forest in a tropical monsoon region and its validation

A soil-plant-air continuum multiplayer model was applied to a deciduous forest in a tropical climate. Two numerical experiments with different seasonal patterns of leaf area index (LAI) were carried out. The first experiment involved seasonally varying LAI, and the second experiment applied an annually constant LAI. The first simulation captured the measured seasonal changes in soil surface moisture; the simulated transpiration agreed with seasonal changes in heat pulse velocity, corresponding to the water use of individual trees. The second simulation greatly changed the simulated amounts of both soil evaporation and evaporation from a wet canopy (interception) in dry seasons, compared with the first simulation, implying the importance of seasonally varying LAI on the water budget.

b-3. Impact of extensive irrigation around yellow river on cloud formation

The impact of extensive irrigation on cloud formation was estimated using a high-resolved (3km grid intervals) mesoscale atmospheric model. Figure 5a shows the distribution of clouds simulated by the numerical model at 14 Local Time on 4 August 2005. The green areas represent the assumed extensive irrigation in the model. Lower temperature is simulated over the irrigated area than one over the surrounding dry area (Fig.5c). The clear contrast of the surface temperature results in the land-use-induced circulation, which generates the clouds shown as C'1 and C'2 in Figure 5a. On the other hand, almost no clouds appear over the irrigated area. The land-use-induced circulation also suppresses the cloud over the irrigated area. The results were consistent with the distribution of clouds observed by the AQUA/MODIS. In contrast Figures. 5b and 5d show the results of numerical simulation assuming no irrigation. The C'1 and C'2 are obscure and numerous clouds appear over the area where irrigation is assumed in the previous simulation (Fig.5b). The contrast of surface temperature is quite small (Fig.5d).

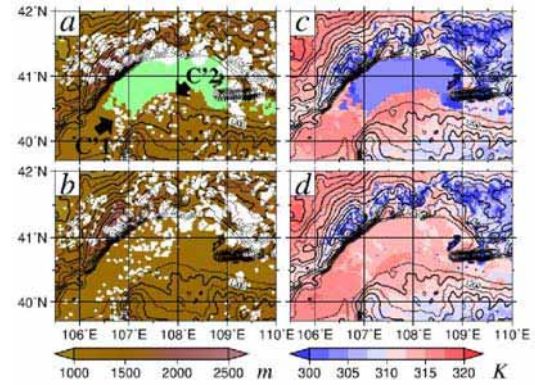


Fig. 5 (Left) Distributions of clouds at 14 LST and (right) surface temperature at 12 LST simulated by the models (top) assuming irrigation and (bottom) assuming no irrigation on 4 August 2005. (a) The green areas show the irrigated areas. (Kawase et al, 2008, Geophysical Research Letters)

b-4. Past change and future prediction of Mei-yu rainband in China

Figure 6a shows ten-year mean precipitation observed in June during the 1990s. These data were provided by the China Meteorological Administration. Large amount of rainfall is observed over the south to the Yangtze River. The amount of rainfall is quite small over the north to the Yangtze River. Figure 6b shows the difference of precipitation between the 1960s and 1990s. Blue shading indicates that precipitation increased from the 1960s to the 1990s. Precipitation increased over the downstream area of Yangtze River. Serious floods frequently occur there.

The distribution of precipitation was simulated very well by the regional climate model using the ECMWF 40 year Re-Analysis Data (ERA40) as an initial and lateral boundary conditions (hereafter, Hindcast run) although the precipitation was a little overestimated for all of Southern China (Fig.6c). The difference of precipitation between the 1960s and 1990s simulated by the regional climate model is quite similar to the observation (Fig.6b). Figure 6e is the same as Figure 6b but the results of the Pseudo Climate Simulation (hereafter, PCS run). The PCS run is almost same as above conventional regional simulation but the lateral boundary condition of the regional climate model is a composite of the six hourly reanalysis data in the 1990s and the difference of monthly mean values between the present climate in the 1990s and the past climate in the 1960s. Even in the PCS run, the change in

the precipitation is simulated well (Figu.6e) .

These results suggest that the change in the precipitation is more strongly controlled by the change in the long-term variation of large scale atmospheric circulation than by the change in daily variations of precipitation process.

The PCS run can be also applied to future projections. The PCS run would reduce the uncertainty caused by the natural variability in the simulated climatic change and exclude model biases in the present climatology reproduced by each GCM. The PCS run would contribute to the reduction of the uncertainty of the downscaling method. The reproducibility of the climate change was confirmed by the PCS run in this study, which contributes to project the future regional climate.

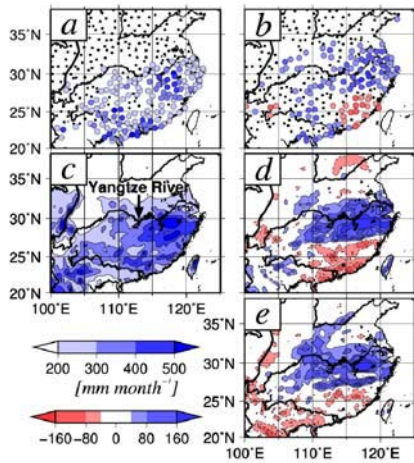


Fig.6 Distributions of ten-year mean monthly precipitation (unit: mm month⁻¹) in June: (a) observations at the stations and (c) simulation by the Hindcast run in the 1990s. Differences in precipitation between the 1960s and the 1990s (b) observed at the stations, (d) simulated by the Hindcast run, and (e) simulated by the PCS run. In Figs. 6b, 6d, and 6e, blue (red) shading indicates that precipitation increased (decreased) from the 1960s to the 1990s. (Kawase et al, 2008 submitted to SOLA) .

c. Cloud/Precipitation Process Group

c-1.Reproducibility evaluation of extreme precipitation in the Baiu season using a cloud-system-resolving model

The reproducibility of extreme precipitation in the Baiu season around Japan was evaluated using a non-hydrostatic cloud-system-resolving regional atmospheric model with a horizontal grid size of 5km (5km-NHM) . Precipitation is explicitly produced by cloud physics schemes with bulk parameterization. For the outer condition of 5km-NHM, which is an atmospheric general circulation model with a horizontal grid size of

about 20km (20km-AGCM) , precipitation is produced by the convective parameterization and large-scale condensation.

To investigate degree of risk of hydrological disasters, the mean precipitation amount among three heavy precipitation events that ranked the highest every year (P_{Top3}) at each grid point was used as an index of extreme precipitation. Figure7 shows distributions of P_{Top3} for the accumulation periods of 1, 6, and 48 hours with 20km-AGCM, 5km-NHM, and observation. The P_{Top3} for shorter accumulation periods is useful index in association with short-span heavy precipitation induced by cumulonimbus clouds. Steep mountains and densely populated areas enhance the significance of short-span heavy precipitation indices in Japan. The P_{Top3} for longer accumulation periods is associated with mesoscale precipitation systems and maximum flow for larger rivers.

The P_{Top3} with 20km-AGCM and 5km-NHM were underestimated in comparison with the observation. However, P_{Top3} with 5km-NHM was reproduced significantly better than that with 20km-AGCM, especially for the shorter accumulation periods. The difference of P_{Top3} for the longer accumulation periods between these models was small. For the estimation of extreme precipitation for shorter accumulation periods, non-hydrostatic model with finer resolution is considered to be required.

One of the most noticeable and interesting changes in precipitation over the land areas of Japan projected by 5km-NHM was enhancement of precipitation in the mountainous areas along the Pacific coast of western Japan (not shown) . This enhancement is considered to result in incremental low-pressure induced by the enhancement of moist diabatic heating around Kyushu in which precipitation and updraft was originally large.

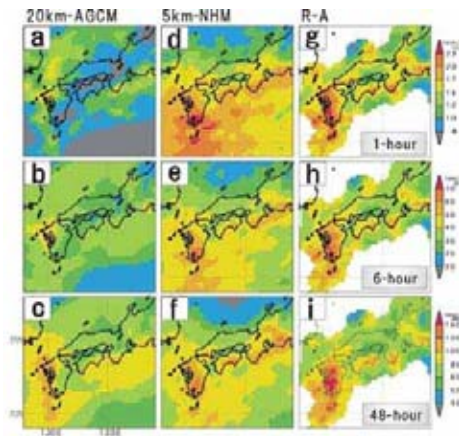


Fig.7 Distributions of P_{Top3} simulated by 20km-AGCM (a, b, c) and 5km-NHM (d, e, f), and observed P_{Top3} (g, h, i). The accumulation periods are (a, d, g) 1, (b, e, h) 6, and (c, f, i) 48 hours. (Wakazuki et al. submitted to JMSJ.)

c-2. A simulation study of a heavy rainfall using a mesoscale-convection-resolving model

A mesoscale-convection-resolving model had been developed and improved to overcome problems of parameterization of subgrid-scale convection in many numerical weather prediction models and general circulation models. It is most effective and efficient when the horizontal grid size is taken to be 5-20 km. The performance of the model has been evaluated by applying it to tropical cyclones, cloud clusters associated with Baiu fronts and diurnal cycle of convection in large islands over the equatorial area. It can be considered that the objectives of model development have been achieved to a fairly satisfactory extent.

In the research year of 2007, numerical experiments were performed to simulate and understand Fukui heavy rainfall, which occurred in July in 2004. A global analysis data of the Japan Meteorological Agency was used as the initial condition. In this case, predicted rainfall was weaker, and the duration time was shorter than the observed. When the amount of low-level water vapor is slightly increased in an area to the west of Fukui district (to the north of San-in district), rainfall pattern similar to radar-AMeDAS data was simulated, as indicated by blue ellipses in Figure 8.

Although the importance of modifying the initial wind field for improvements of the heavy rainfall prediction was pointed out by a previous study, this study suggests that the initial water vapor field (and therefore, latent instability field)

is important to simulate this heavy rainfall event. In addition, the importance of convective instability has been emphasized by many researchers. However, it is also strongly suggested that latent instability is essential to the heavy rainfall event. Convective instability is not released in the numerical experiment.

The structure and evolution of the mesoscale convective system simulated by the numerical experiment suggest that the so-called back-building plays an important role in Fukui heavy rainfall. This mechanism is brought by westerly flow with strong low-level vertical shear and by latent instability around and to the south of the Baiu front. The model simulates well the distributions of the grid-resolved and subgrid-scale cloud water and rainwater qualitatively.

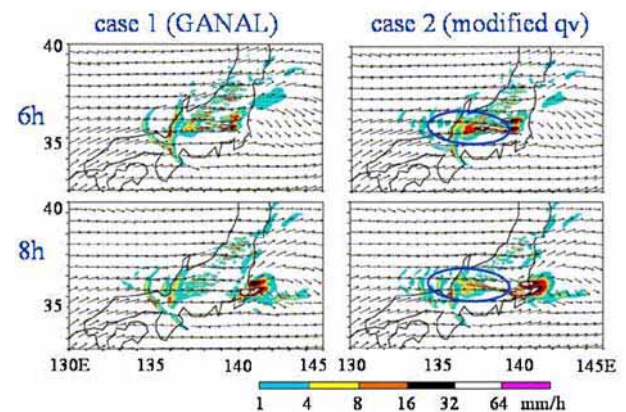


Fig.8 Distributions of the rainfall intensity in Fukui heavy rainfall simulated by the mesoscale-convection-resolving model at 6 hours (upper) and 8 hours (lower) after the initial time. The left panels show the results in case 1 in which global analysis data of JMA is used, and the right shows those in case 2 in which water vapor amount is increased (with a maximum value of 1 g/kg) so that latent instability may become stronger.

(3) Atmospheric Composition Research Program

This Program aims at evaluation of emission, transport, transformation and deposition processes of atmospheric trace species relevant to climate change and air pollution in Asia-Pacific region including Eurasian Continent, and at prediction of atmospheric composition change including climate change feedback by studying relations between regional air quality change and global air pollution, and air pollution and climate change. In order to accomplish these aims, this Program studies the processes of intercontinental and intra-continental long-range transport of air pollutants, and tropospheric photochemical reaction, and physical and chemical characterization of aerosols. It also targets to evaluate the sources and sinks of greenhouse gases such as CO₂ and methane, and to elucidate the cause of their variability by studying the spatial and temporal variability of concentration, and isotope ratio of carbon and oxygen. Further, future prediction of air quality change in Asia Pacific region is studied through the emission inventories of air pollutants and greenhouse gases.

In this fiscal year, results for continuous observation of ozone, CO and black carbon (BC) in China, Russia and Kyrgyz, and intensive campaign for ozone, aerosols, and their precursors at Mt. Tai in China are reported. The data has been analyzed by means of regional chemical transport models. Intercomparison of inverse calculation of CO₂ flux by FRCGC-NIES and JMA models has been conducted. As for the development of chemical weather forecasting system, comparison of three boundary layer parameterization schemes has been made.

Research Results

a. Observation of ozone and black carbon in China, Russia and

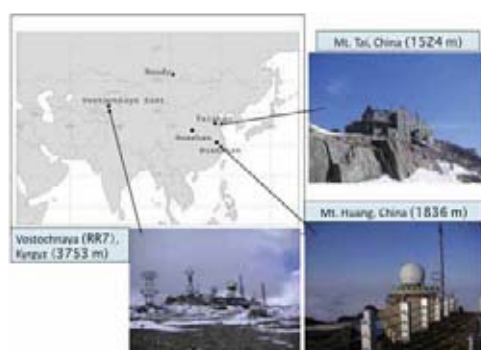


Fig.1 Observational stations for O₃, CO and BC with pictures. Other sites without a picture are for O₃ and CO.

Kyrgyz

Figure1 shows the location of year-around observational sites at Vostochnaya in Kyrgyz, Mt. Tai and Mt. Huang in China where O₃, CO and black carbon (BC) have been measured, and at Mondy in Russia and Mt. Hua in China where O₃ and CO have been measured. Figure2 presents the data of BC obtained at Vostochnaya, Mt. Tai and Mt. Huang showing the yearly averaged concentration of 0.1, 2.3 and 0.99 $\mu\text{g}/\text{m}^3$, respectively. Comparing with the literature values, the concentration at Vostochnaya, 3,700 m high in Central Asia is comparable to that obtained at White Face Mountain in New York State, USA. On the other hand, The concentration at Mt. Tai, which is located in the area of most serious regional pollution in China, is about the same as in Tokyo in 2003-2005, whereas one at Mt. Huang, which is located at the outskirts of the regional pollution is close to the value in Tokyo in recent years after more stringent control of diesel automobile exhaust has been introduced.

Figure3 shows the seasonal variation of surface ozone concentrations at the three mountain sites in China comparing with that at Mondy, which is a remote baseline station in East Siberia. It can be seen that ozone concentrations obtained at the sites in the regionally polluted area in China in winter when there is no photochemical activity, are the same as at Mondy.

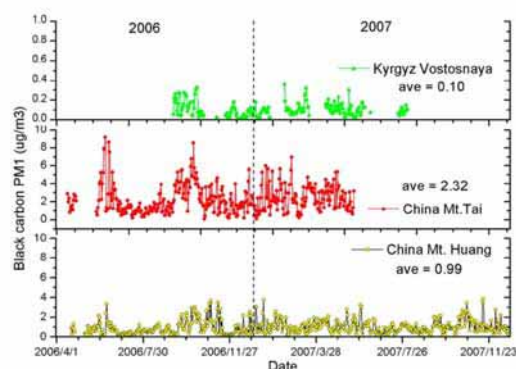


Fig.2 Observational stations for O₃, CO and BC with pictures. Other sites without a picture are for O₃ and CO.

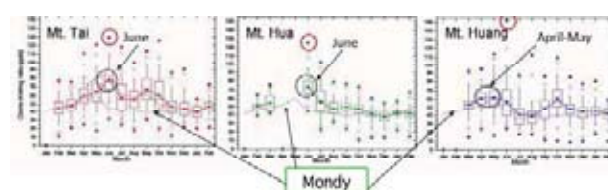


Fig.3 Seasonal variation of ozone at the three mountains in China as compared with that at Mondy, Russia.

On the contrary, ozone concentration maximizes in June at Mt. Tai and Mt. Hua in China reaching at monthly averaged concentrations of 80 and 75 ppbv, which are higher than at Mondy by 35 and 30 ppbv, respectively. These values are considered to be the contribution of in situ photochemical production in this region. One hour averaged values at these sites reached to more than 130 ppbv, which is comparable to those observed in the photochemical air pollution in big urban cities. Meanwhile, seasonal peak of ozone concentration at Mt. Huang shifts to April-May with the maximum monthly averaged value of 65 ppbv demonstrating that the concentration is lower than the North China Plain. The earlier peak of ozone at Mt. Huang reflects the influence of summer monsoon starting in June at the lower latitude and near the coastal line.

b. Photochemical production and transport of ozone at the three mountains in China

Seasonal variation of ozone concentration obtained by the observation at the three mountains in China has been analyzed for the contribution of photochemical production and transport by a regional chemical transport model. A Nested Air Quality Prediction Modeling System (NAQPMS) with 81 km $\times$ 81 km horizontal resolution was used for the analysis in one whole year. Figure4 shows the comparison of the model output with observational data at the three mountain sites in China after the validation of the model using the observational data at WMO/GAW and EANET stations. As shown in the figure, June peak at Mt. Tai and Mt. Hua, and spring peak at Mt. Huang

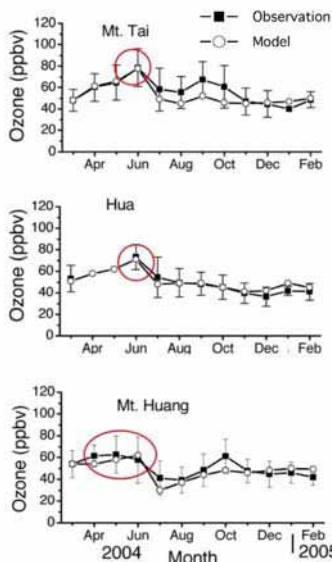


Fig.4 Comparison of modeled seasonal variation of ozone at Mt. Tai, Mt. Hua and Mt. Huang with observation.

have been well reproduced. Summer minimum and second peak in autumn is seen at Mt. Tai and Mt. Huang, whereas summer minimum is not clearly seen at Mt. Hua. This can be attributed to the influence of oceanic air mass due to summer monsoon at Mt. Tai and Mt. Huang, which are located in relatively close to the coast, in contrast to Mt. Hua, which is located in inner land and scarcely affected by the oceanic air.

Fig.5 depicts spatial distribution of ozone production rate per day averaged in summer months (June-August). It can be seen in the figure that Central East China including Mt. Tai and Mt. Hua is the most active ozone production area in East Asia with the amount of more than 15 ppb/day. In contrast, averaged ozone production rate is 8-15 ppb/day from Korea to Japan.

Table 1 shows the contributions of photochemical production and transport of ozone at Mt. Tai, Mt. Hua and Mt. Huang. At Mt. Tai and Mt. Hua, ozone in June and July is exclusively due to photochemical production and transport is a small out-flow. The amount of photochemical production at Mt. Tai is larger than at Mt. Hua by a factor of two. On the contrary, photochemical production at Mt. Huang is a bit smaller than at Mt. Hua, but inflow transport is comparable to the photochemical

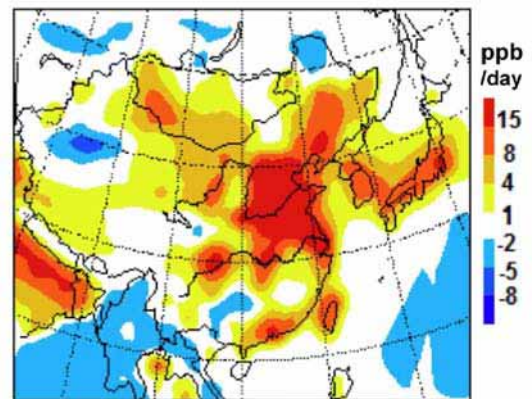


Fig.5 Net photochemical production of ozone in summer (June-August) (ppb/day).

Site	Month	Photochemical Production	Transport
Mt. Tai	June	25.4	0.6
	July	20.7	-4.0
Mt. Hua	June	12.1	-1.3
	July	10.0	-2.1
Mt. Huang	June	10.4	8.1
	July	9.1	4.2

Table 1 Net photochemical production and net transport of ozone at Mt. Tai, Mt. Hua and Mt. Huang.

production in June. Even in July inflow transport contributes about a half of in situ photochemical production at Mt. Huang. The ozone pollution in the Central East China has thus been characterized in this study.

c. Data analysis of intensive field campaign at Mt. Tai in China

As a part of the project " Spatial and temporal variability and climate impact of ozone and black carbon in Asia" granted by Global Environmental Research Fund, Ministry of the Environment, Japan, a month-long intensive field campaign at Mt. Tai has been conducted in June 2006, and data analysis has been made in 2007. In addition to the JAMSTEC scientists, those in National Institute for Environmental Studies, Tokyo Metropolitan University, Hokkaido University, Institute of Atmospheric Physics (Chinese Academy of Sciences) , and Fudan University have joined this campaign.

Figures 6 and 7 show the time series of the concentrations of BC/EC and O₃/CO/NO_x/NO_y obtained during the campaign, respectively. From Fig. 6 average concentration of BC (PM_{2.5}) by MAAP is obtained at 3.7 $\mu\text{g}/\text{m}^3$ (maximum hourly averaged value is 40.8 $\mu\text{g}/\text{m}^3$) , and those of O₃, CO, and NO_x and NO_y are obtained at 82, 560, 1.1 and 6.7 ppbv, respectively, from Figure7. Very high concentrations of BC, CO and NO_x on June 5-7, and 11-13 as seen in Figures 6 and 7 (hatched period) are due to biomass burning after harvesting of spring wheat, and it appeared that such agricultural waist burning has significant impact on ozone and aerosol pollution in the North China Plain in June. Further, diurnal variation seen particularly in the later half of June in Figure6, is due to the diurnal variation of mixing layer height.

From the analysis of the observational data, radiative forcing of O₃ and BC at Mt. Tai in June has been estimated as shown in Table 2. The radiative forcing of O₃ and BC at the tropopause are 0.64 and 2.75 W/m². It is concluded that they exert large radiative impact regionally as compared to long-lived greenhouse gases.

d. Intercomparison of inverse calculation of CO₂ flux by FRCGC-NIES and JMA models

In this program, source-sink flux estimation of CO₂ with

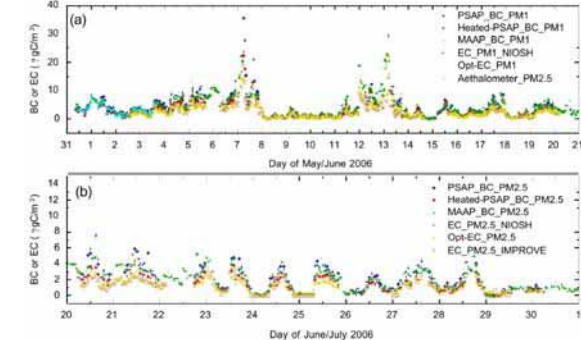


Fig. 6 Concentrations of BC and EC measured y several different types of instruments during the Mt. Tai campaign in June 2006.

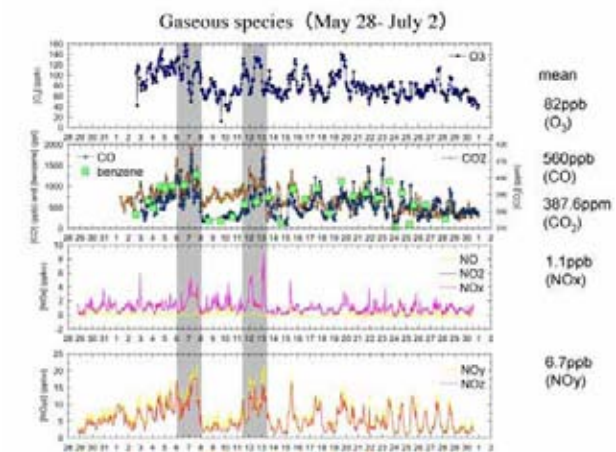


Fig. 7 Concentrations of O₃, CO, and MAAP-BC observed in the Mt. Tai campaign in June 2006.

Species	Radiative sensitivity	Global			North China Plain		
		Present	Pre-industrial	RF W m ⁻²	Present	Pre-industrial	RF W m ⁻²
CO ₂	0.01677 W m ⁻² ppm ⁻¹	379 ppm	280 ppm	1.64	390 ppm	280 ppm	1.84
CH ₄	0.00045 W m ⁻² ppm ⁻¹	1774 ppb	715 ppb	0.48	1900 ppb	715 ppb	0.54
O ₃	0.032 DU ⁻¹	40 DU	30 DU	0.32	50 DU	30 DU	0.64
BC	1.25 W mg ⁻¹	0.4 mg m ⁻²	0.2 mg m ⁻²	0.25	2.4 mg m ⁻²	0.2 mg m ⁻²	2.75

RF: Radiative Forcing

Table 2 Radiative forcing of O₃ and BC at Mt. Tai in June calculated from the observational data

the highest spatial segmentation (globally 64) by high resolution (1° × 1°) FRCGC/NIES transport model has been conducted with the use of Earth Simulator. In this fiscal year, as a part of Earth Simulator Project, Intercomparison between JMA and FRCGC/NIES models has been made under the same conditions collaborating with Japan Meteorological Agency. Figure 8 compares the 24-regional segregation so far used in the international intercomparison program (TransCom3) , and the 64-segregation used in the present study. Among observational data at surface by ground-based and shipboard measurements and in the upper troposphere by aircrafts, only those whose difference from the forward model simulation is less than 2 ppmv were used for the inverse modeling.

The comparison for carbon flux anomaly for terrestrial and ocean during 1991-2005 obtained by the FRCGC/NIES and JMA modeling is shown in Figure9. As shown in the figure, inter-annual variability of terrestrial carbon flux agreed excellently while the oceanic flux obtained by JMA is found to be smaller than FRCGC analysis. Further, although the inter-annual variability for oceanic flux is scarcely seen by JMA analysis, larger variability is seen in the FRCGC analysis.

e. Boundary layer parameterization in the Chemical Weather Forecasting System

Press release on the development of chemical weather forecast system applied for Tokyo Metropolitan area has been made on August 22, 2007. In this fiscal year, the study was further developed to discuss boundary layer parameterization for the chemical weather forecasting system applied to Tokyo Metropolitan Area. Figure10 shows the model Domain 1

(Japan Area) and Domain 2 (Tokyo Metropolitan Area). A regional model WRF/Chem using the horizontal resolution of 15 and 5 km, respectively, has simulated domains 1 and 2. In the present study, the following three PBL schemes were employed being incorporated into the WRF/Chem; 1) Mellor-Yamada Level 2.5 Era Model (MYJ), 2) Yonsei University (YSU), and 3) NCEP Global Forecast System (GFS). It has been found that all these three schemes reproduced near surface temperature and wind direction associated with land-sea breeze circulation with the correlation coefficients of 0.82-0.83, and 0.62-0.72 at the 78 and 79 monitoring sites respectively. On the other hand, the correlation coefficient and mean bias (MB) for surface ozone was 0.62-0.72 and 10.3-32.8 ppb, respectively, resulting in large differences for the three PBL schemes. Figure11 shows an example of comparison between the observational and calculated ozone distribution at 15 JST on July 29, 2005. Among the three schemes it is seen that MYJ resulted in the best agreement with the observation. Also Figure 12 compares the calculated and observational mean wind direction during nearly one month between July 20-August 23, 2005. As seen in the figure, the calculated timing of the inflow of sea breeze is the closest to the observation for MYJ, and it is much delayed for YSU and GFS. From these results, it has been concluded that the MYJ scheme gives the best agreement with observation among the three PBL schemes to reproduce meteorological parameters and ozone concentration field in the Tokyo Metropolitan Area.

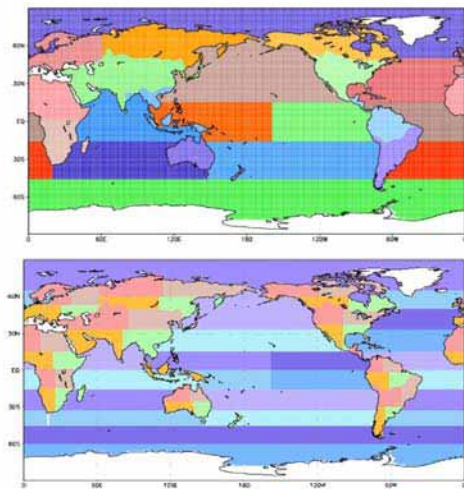


Fig. 8 Regional segmentation of CO₂ flux employed in the previous study (upper) and in the present study (lower).

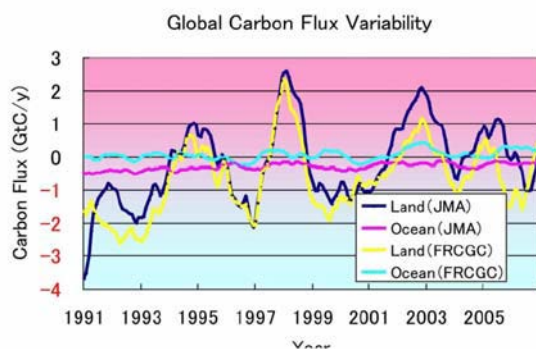


Fig. 9 Comparison of interannual variability of CO₂ flux anomaly in the terrestrial and oceanic area calculated by JAMSTEC/NIES and JMA models.

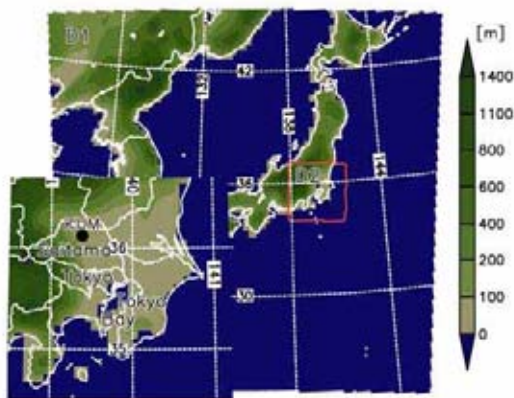


Fig.10 Model domain used for chemical weather forecast system. Insert is the enlarged map of Domain 2. The black dot shows Kumagaya site.

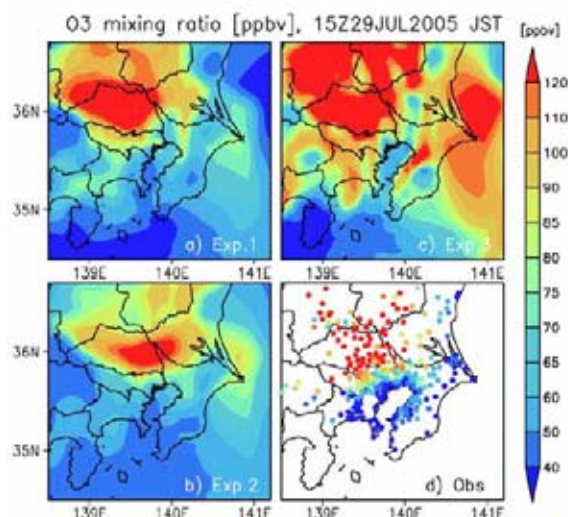


Fig.11 Comparison of near surface O_3 concentrations calculated by using the boundary layer scheme of a) MYJ, b) YSU, and c) GFS, with d) observation. (15 JST July 29, 2005)

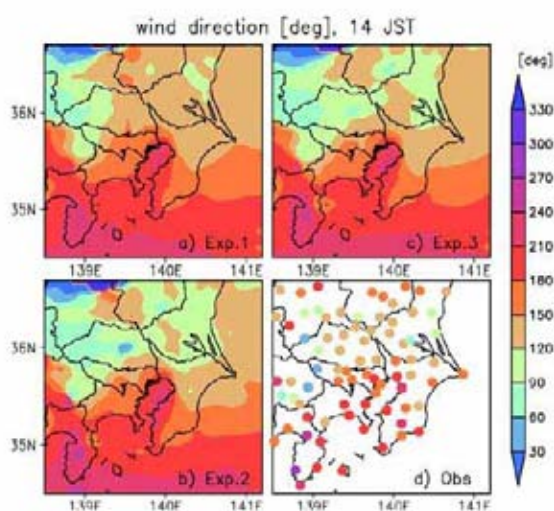


Fig.12 Comparison of average wind direction distributions calculated by using the boundary layer scheme of a) MYJ, b) YSU, and c) GFS, with d) observation. (14 JST July 28-August 23, 2005)

(4) Ecosystem Change Research Program

This FY our efforts have been focused to develop original ecosystem models to elucidate ecosystem mechanisms as well as to predict ecosystem changes under the climatic changes in both terrestrial and marine environments. At present, ECRP is consist of three research groups as described below.

1) Terrestrial Ecosystem Model Group

a. Carbon-nitrogen model is developed by improving a terrestrial ecosystem model (Sim-CYCLE). In addition, a dynamic global vegetation model (DGVM), regional high-resolution carbon budget model, and individual-based forest dynamics model is developed for the purpose of development of the integrated model.

Soil displacement by water erosion was included into Sim-CYCLE, a process-based terrestrial ecosystem model, indicating that the process should exert an important effect on long-term carbon budget than expected (Fig.1). The research outcomes including future projection based on projected climatic change and land-use change were published from Geophysical Research Letters (Ito, 2007). Methane and nitrous oxide exchange schemes were gradually incorporated into Sim-CYCLE, so that regional scale evaluation of net greenhouse gas budget is plausibly quantified with adequate accuracy. As to climate-carbon cycle interaction, simulation results using the coupled AGCM-Sim-CYCLE model were presented to several international conferences and submitted as a full article, focusing on its temporal-scale dependency (Kato et al., in

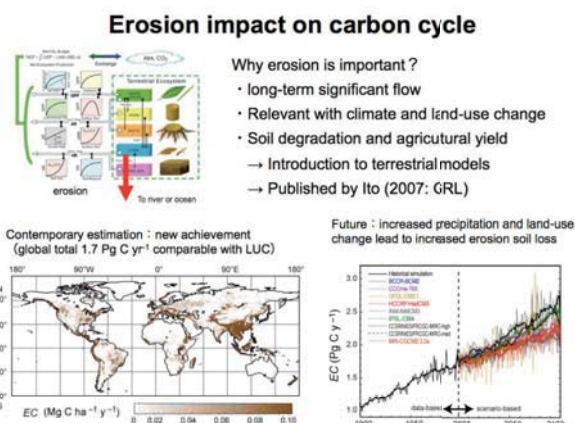


Fig.1 Impacts of soil erosion on the global carbon budget

revision). Also, carbon budget of East Asian terrestrial ecosystems estimated by the 1-km mesh model was published on the basis of GERP-S1 project (Ito, in press).

We continued development of a model simulating major processes of atmosphere-land surface greenhouse gas exchange. In particular, methane production under anaerobic conditions such as wetlands and paddy fields would be newly introduced. As to the high-resolution model, simulation area would be expanded to Southeast Asia and southern Siberia to cover the Asia region.

Major processes of terrestrial nitrogen cycle were introduced into Sim-CYCLE, and fully coupled with carbon cycle. And, a methane production scheme was applied to wetlands and paddy fields to establish a greenhouse gas exchange model. A nitrous oxide emission scheme was also included into our global model, so that we could perform preliminary simulations for three major greenhouse gases. This model allows us to evaluate net greenhouse gas budget of terrestrial biosphere and provides us deeper insights on ecosystem functions under global warming. A paper on site-scale validation of the model was submitted (Inatomi et al., submitted).

b. Explore impacts of global climatic changes on vegetation distribution and functions using SEIB-DGVM, an individual-based dynamic global vegetation model.

Using the SEIB-DGVM, we examined transient changes in vegetation distribution and fractions for the next 100 years (in prep). For vegetation responses, there was a significant time lag that differed depending on the migration scenario used: a more rapid migration scenario facilitated invasion of the forest biome and incremental increases in net primary production and biomass. This result motivated us to explore more sophisticated and reliable ways of modeling migration toward developing the next generation of dynamic global vegetation models. To enable analysis of interaction between terrestrial surface and atmosphere, we have developed communication program for integrating the SEIB-DGVM to an AOGCM (Atmospheric Ocean General Circulation Model). In the fiscal year 2008, we are going to initiate 'on-line simulations' using this integrated earth-system-model.

We have applied the model to an east Siberian larch forest by incorporating empirical rules for allometry, allocation, and phenology observed at a larch forest (Sato et al., submitted). After calibration, the model reconstructed the post-fire succession patterns of forest structure and carbon cycling (Fig.2). It also reconstructed seasonal changes of carbon, water and energy cycling in a mature larch forest. When the model was applied to the entire larch-dominated region in eastern Siberia, simulated result was comparable for latitudinal gradient of aboveground biomass.

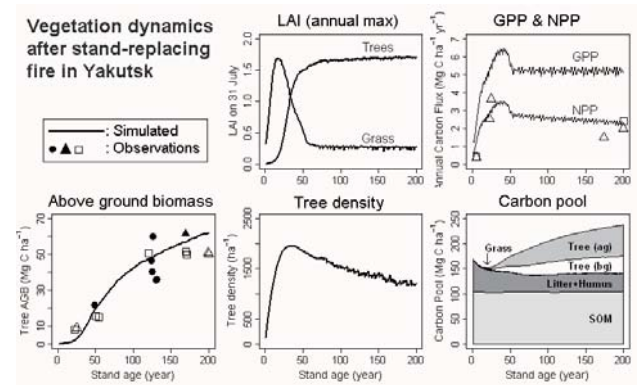


Fig. 2 Application of the SEIB-DGVM to Siberian larch forest

2) Marine Ecosystem Model Group

a. Marine Ecosystem Simulation in a high resolution OGCM

Using a high resolution ocean general circulation model combined with a simple ecosystem model (Nutrient-Phytoplankton-Zooplankton-Detritus, or NPZD type), with a horizontal resolution of 0.1 degrees, we have diagnosed the variability of chlorophyll maximum in the meso-scale eddies in the subtropical-subarctic transition region and Kuroshio Extension region. We have also published a study on the variability of surface chlorophyll influenced by the meso-scale eddies such as the Costa Rica Dome in the eastern tropical Pacific Ocean using the high-resolution model and satellite observation data. To investigate the dependency of the results in tracer simulations on the model grid resolution, an experiment of CFC-11 with a 0.5 degrees model has been performed.

b. Study of marine ecosystem responses to climate change

b-1. International cooperative study on the long-term changes in marine ecosystem processes.

We participated in the SCOR Working Group project

"Global comparison of zooplankton time-series" and developed a series of statistical methods for the effective regional comparison of ecosystem changes. The Working Group plans to hold a special session on this topic during the International symposium "Effects of Climate Change on the World's Oceans" in May 2008, and publish a special issue of a scientific journal to present the accomplishments of the working group activities.

We also conducted the study on the Pan-North Pacific comparison of zooplankton time-series based on the stable isotope ratio of the major zooplankton species, *Neocalanus* spp. collected in the western, central and eastern North Pacific during 1960s - 2005 under the collaboration of domestic and international organizations. From the interannual variation of Nitrogen stable isotope of *Neocalanus*, we found the bottom-up control of food web structures, which might be derived from temporal variation in environmental conditions of the respective regions. This study was funded by the Grant-in-Aid for Scientific Research.

b-2. Comparative study of long-term changes in terrestrial and marine ecosystems

We analyzed stable isotope ratio of Salmonid fish scales taken in the Lake Baikal and western North Pacific for the past 50 years. We found the quasi-bi-decadal synchrony in the stable isotope ratio of the fish, which inhabited in the completely remote and independent ecosystems each other. This result suggested that dynamics of the Okhotsk High and Aleutian Low might influence the atmospheric and hydrographic conditions of Siberia and North Pacific at the same timing in decadal scale.

b-3. Analysis of seasonal and interannual variability of chlorophyll a and primary productivity using satellite data

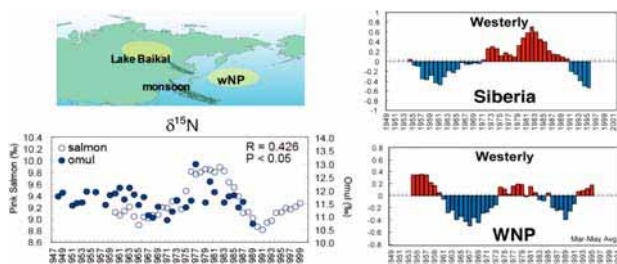


Fig.3 Left bottom: Time-series of nitrogen isotope ratio in the scales of Ormul in Lake Baikal and pink salmon in the western North Pacific (the long-term trend is removed) . Right: Long-term variability of anomalous westerly velocities over the Siberia and western North Pacific.

We made a classification map in the North Pacific including some marginal Sea (Japan Sea, Okhotsk Sea and Bering Sea) based on magnitude of seasonal change (standard deviation) and peak chl-a values during spring bloom using 11-years' ocean color satellite data, and examined relationships between chl-a concentrations and sea surface temperature anomalies at each regions. The results show warmer sea surface temperature corresponds to higher chl-a concentrations in the Bering Sea and Oyashio regions. Contrastively, opposite patterns were seen in Gulf of Alaska and Kuroshio regions. In FY2008, we will examine those mechanisms in detail and discuss the relation to climate change. As part of same research using ocean color data, interannual variability of spring bloom timing in the North Pacific was investigated. The results show timing of spring blooms in northwestern and adjacent sea around marginal sea region was earlier in El-Niño year (Warmer phase) and later in La-Nina year (Cooler phase). On the other hand, opposite pattern was seen in offshore south-eastern region. Our two major research topics suggest that oceanic environment or marine ecosystem response to climatic forcing is different from each regions.

b-4. Development of pCO₂ model using satellite data

A model to estimate the partial pressure of carbon dioxide (pCO₂) for the North Pacific was developed using satellite data last year (In cooperation with Nagoya University). The model derived pCO₂ results showed good agreement with ship-board data within an error of 15-18 micro-atm. This method suggests that it is possible to evaluate basin-scale pCO₂ trends using remote sensing data. However, we cannot describe seasonal, interannual variations and effects due to climate change such as El-Niño and La-Nina events in detail. Now first version of global algorithms was completed.

c. Modelling of interannual variability of marine ecosystem and International collaboration

Using a global 3-dimensional marine ecosystem model (COCO-NEMURO) combined with carbon cycle based on the OCMIP (Ocean Carbon-cycle Model Intercomparison Project) protocol, we have investigated the impact of climate variability in the North Pacific such as the Pacific Decadal

Oscillation (PDO) to the marine ecosystem and air-sea CO₂ flux variability. The model simulates the climate shift in 1970s including decrease of sea surface temperature, increasing of primary production and air-to-sea CO₂ flux after the climate shift. We participated a workshop of the Dynamic Green Ocean Project and proposed a new international research project named Marine Ecosystem Modelling Intercomparison Project (MAREMIP) with a research group in the United Kingdom to progress the development and inter-comparison of the marine ecosystem models. The data for the Inter-comparison experiments has been prepared. We also developed the NEMURO model combined with an iron process model and performed a preliminary experiment (Fig.4). The results from this new model exhibit much improvement in chlorophyll in the eastern tropical Pacific and Southern Ocean where biomass in the previous model was exaggerated compared with the satellite data.

3) Ecosystem Spatial Observation and Modeling Group

a. To develop a new observation technique of the Photosynthetically Active Radiation (PAR).

We developed an algorithm for estimating the PAR by satellite data especially over Asia. Two surface stations for PAR monitoring were implemented in Borneo Island. Those surface sites were maintained by us and the PAR data derived from their PAR sensor were analyzed and investigated. Simultaneously a special PAR sensor that was able to image the hemispheric distribution of PAR in the sky was developed.

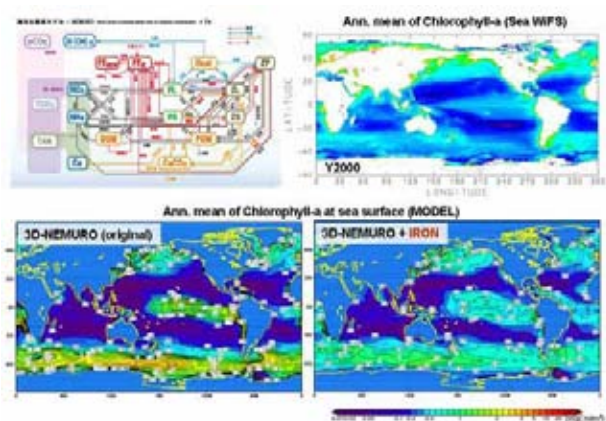


Fig.4 Schematic diagram of the 3-dimensional marine ecosystem model (COCO-NEMURO) combined with iron processes (top left). Comparison of chlorophyll-a among satellite observation (top right), the simulated result using the model without iron process (bottom left), and with iron process (bottom right).

Moreover, data of Multi-functional Transport Satellite (MTSAT) were transferred to ECRP for the accurate monitoring of PAR.

The algorithm for estimating Leaf Area Index (LAI) by satellite data was developed. The validation of the estimation was conducted by using ground truth LAI data in eastern Siberia observed in 2000. The ground truth information for the LAI and biomass over grassland in Asia was acquired by in situ measurement in Tibetan Plateau, and used for constructing a map of LAI distribution (Fig.5). The ground truth for paddy rice field was also measured for developing the LAI estimation algorithm. The effect of the forest canopy and floor greenness for the LAI estimation was evaluated by aircraft remote sensing data that were carried out in eastern Siberia in 2000.

Data of the sensor "Phased Array type L-band Synthetic Aperture Radar (PALSAR)" of the satellite "Advanced Land Observing Satellite (ALOS)" were provided from Japan Aerospace Exploration Agency (JAXA). In situ observation was executed over the forest-tundra ecotone in Alaska for the development of the estimation algorithm of the forest above-ground biomass by ALOS/PALSAR.

A vegetation transition model in Mongolia was improved concerning with the interaction between climatic-edaphic conditions and the realized vegetation state at the topography scale. Field surveys on the vegetation and climate conditions were executed in Mongolia for the development of the model. The seasonal and interannual characteristic of Siberian larch forest

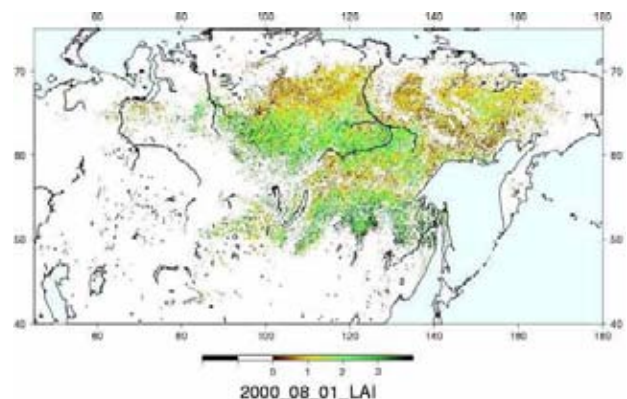


Fig.5 Distribution of Leaf Area Index (LAI) over the larch forest in eastern Siberia estimated by satellite data (mean of first 10 days in August 2000).

and tropical forest was surveyed by satellite data, and its impact on the carbon cycle was investigated. Long term snow cover change, which influences vegetation phenology was also investigated. The study of the global relationships of vegetation-air temperature, vegetation-precipitation, and vegetation-PAR was developed

(5) Global Warming Research Program

The principal goal of the Global Warming Research Program is projection and understanding of global warming. Working towards this goal, three groups, Global Warming Research Group, Coupled Model Development Group and Paleoclimate Research Group, are involved in numerical experiments for present day, future global warming and paleoclimate using the Earth Simulator, and in climate model development.

As the IPCC AR4 process was over in FY2006, all groups have slightly adjusted their research plan with AR5 in mind. Members of the Global Warming Research Group are engaged in critical analyses of model outputs presented to AR4 in order to understand model performance better.

The Coupled Model Development Group is engaged in studies to improve model physics in the CCSR/NIES/FRCGC Atmosphere Ocean Coupled General Circulation Model (henceforce, this model is called MIROC, and the atmospheric part of it MIROC AGCM) and to clarify characteristics of model biases. This group is a core group of the coupled model development at FRCGC, and members of the other groups of GWRP as well as other programs at FRCGC have joined in the activities.

The Paleoclimate Research Group is engaged in various numerical experiments, on the onehand, to understand the mechanisms of paleoclimate changes and on the other, to verify MIROC, strengthening cooperation with other related research groups.

Research Results

a. Improvement of boundary layer and cumulus parameterization

An improved version of Mellor-Yamada scheme based on Nakanishi and Niino (2004) is implemented in MIROC

AGCM. Main differences of this scheme from the past scheme are (1) improved treatment of mixing length and (2) pressure correlation terms, (3) updated closure constants based on LES results and (4) higher level in the hierarchy of the scheme. Main Improvements are seen in vertical distribution of water vapor and cloud water in the lower troposphere (Fig.1). Large dry biases around 850hPa are almost eliminated with this scheme. Low level clouds tend to be lifted up making the result closer to observations.

A new cumulus parameterization is developed. Its main characteristics are (1) lateral entrainment rate changes vertically depending on buoyancy and vertical velocity of cloud air parcel, (2) updraft ensemble is spectrally represented according to updraft velocity at cloud base and (3) cloud base mass flux is determined by the same method as the prognostic Arakawa-Schubert scheme. The result shows great improvements such as (1) equatorial moist Kelvin waves and MJO-like waves are represented without any empirical triggering schemes, (2) double Inter Tropical Convergence Zone (ITCZ) disappears (Fig.2) in the eastern Pacific and (3) South Pacific Convergence Zone (SPCZ) is well represented.

b. Change in climate sensitivity by the improvement of atmospheric boundary layer in MIROC

Since we plan to use MIROC, described above, for the comprehensive global warming research, we have examined the climate sensitivity (the equilibrium change in global mean surface temperature following a doubling of the atmospheric CO₂ concentration) which is a useful measure to identify and characterize a GCM. We have found that the higher-order closure scheme has a large influence on the climate sensitivity

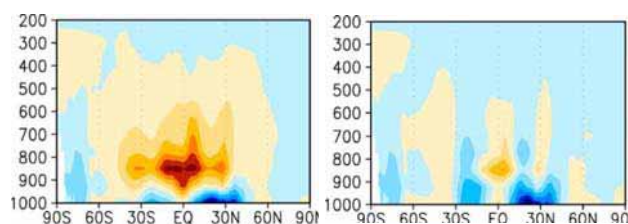


Fig.1 Zonally averaged annual mean specific humidity bias in the experiment with old (left) and new (right) scheme.

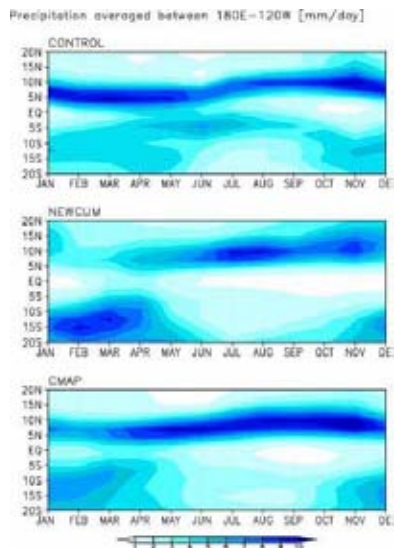


Fig.2 The latitude-time section of precipitation averaged between 180E and 120W in the control experiment (top), new cumulus experiment (middle) and CMAP (bottom).

through the changes in low-level cloud amount.

The globally averaged value of the climate sensitivity of MIROC3.2 is 4.9deg, while the value is 6.0deg when using the new radiation code on the hybrid vertical-coordinate (MIROC4.0b) due to the enhanced radiative forcing. Note that the value of the radiative forcing of the new radiation code displays a favorable comparison with those obtained from a line-by-line calculation and other GCM simulations. When applying the higher-order closure scheme for a vertical mixing process to the MIROC4.0b, the value of the climate sensitivity is 4.8deg. Since the upward transport of moisture is always enhanced around the lower troposphere and the low-level cloud amount is generally reduced particularly over the Arctic region, when using the higher-order closure scheme, the response of the low-level cloud amount to a doubling of the atmospheric CO₂ concentration is weak.

c. A Climate sensitivity test using a global cloud resolving model NICAM and MIROC AGCM

We have conducted the first climate sensitivity experiment using NICAM with the realistic topography. It has shown the increase of high thin clouds all over the tropics and the subtropics (Fig.3). These characteristics have not been seen in global warming simulations in IPCC AR4. High thin cloud has larger greenhouse effect than the albedo effect. The increase of high thin clouds with the temperature increase works as a positive

feedback, thereby it amplifies climate sensitivity in global warming. Cloud feedbacks in longwave in the simulations for IPCC AR4 show smaller inter-model deviation than in short-wave. It can be possible that current GCMs might have missed uncertainties due to two uncertain processes, i.e. convections in GCMs are substantially biased for their inability of resolving cumulus convection, and because ice phase condensed matters are modeled in a simplified way in GCMs. Development of a cloud resolving model for climate change simulations will be hastened near future. Cloud feedback in the tropics can be a large source of uncertainty in the global warming simulation in the future. It is essential to obtain observational data of physical and radiative properties of ice condensed matter, to understand physical processes and evaluate models.

d. Characteristics of interannual and submonthly variability of North Pacific subtropical high

The characteristics of the North Pacific subtropical high (NPSH) associated with interannual and submonthly variability are investigated using 6-hourly data from ERA-40 with T106 resolution. Figure4. shows scatter plots of the NPSH index (positive and negative values indicate westward extension and eastward retreat of the NPSH, respectively) and submonthly variability of geopotential height at 850 hPa averaged in the western Pacific during 1979-2001. The clear negative correlations indicate that when submonthly variability is large, the NPSH retreats eastward, and vice versa. Correlation coefficients for June and August are -0.66 and -0.68, respectively.

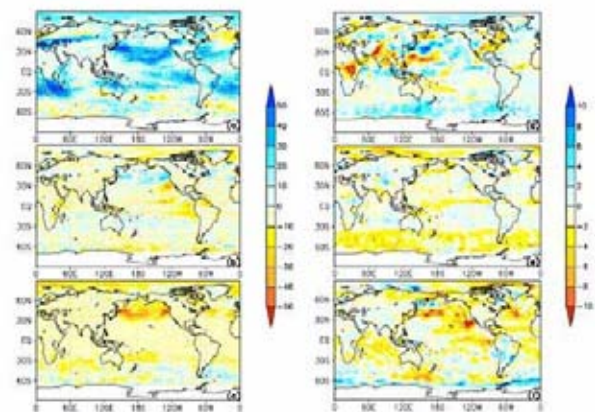


Fig.3 Difference of clouds classified by the ISCCP simulator between the control experiment and the +2K experiment. Panels (a), (b) and (c) are high, middle and low clouds for NICAM. Panels (d), (e) and (f) are those for MIROC.

The regression lines are significant at the 99% confidence level.

The NPSH is most stable and has the smallest interannual and submonthly variability in the western Pacific in June, while the NPSH has largest variability in August among JJA. Therefore, realistic simulations of the climatological distribution and interannual and submonthly variability of the NPSH might be most difficult in August among JJA. This month includes large interannual and intramonthly variability, such as those related to typhoon activities. We have started to analyze more than 20 numbers of multi-model results in order to investigate the possibility of simulating the NPSH including mean state and variability in the climate model.

e. Response of subtropical and tropical cells in the Pacific to global warming and its dependence on ocean model resolution*

Using two atmosphere-ocean coupled GCMs (CGCMs) in which only the horizontal resolution of ocean model is different, resolution dependence on the response of subtropical cells (STCs) and tropical cells (TCs) to global warming, and its influence to sea surface temperature (SST) in the tropical Pacific are investigated.

In the present study, two setups of MIROC3.2 are used. One is a high-resolution setup in which a high-resolution (T106) atmospheric component is coupled with an eddy-permitting ($0.29^\circ \times 0.19^\circ$) ocean component. Hereafter, this setup is denoted by "hAhO". The other employs the high-resolution atmospheric component and a medium-resolution

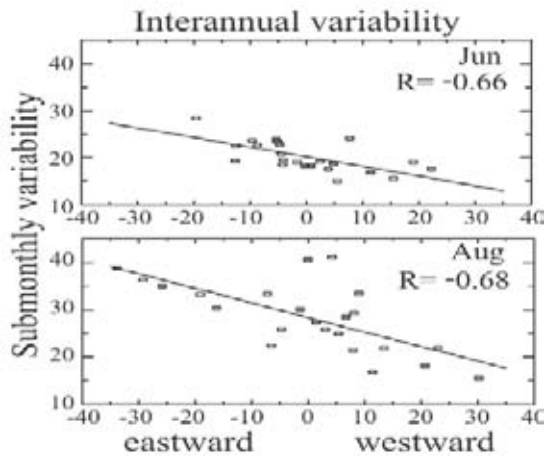


Fig.4 Scatter diagram of the NPSH index and submonthly variability of Z at 850 hPa averaged for the index area (125°E - 150°E , 17°N - 32°N) from June to August during 1979-2001. The solid line is the linear regression line. Correlation coefficient values are shown in the upper right as R. Regression lines are significant at the 99% confidence level.

($1.4^\circ \times 0.5$ - 1.4°) ocean component, and is hereafter denoted by "hAmO". Two experiments are conducted with each of the above setups. One is a simulation for a control climate state under pre-industrial condition. The other is a global warming experiment, in which the atmospheric CO_2 concentration is increased at the rate of $1\% \text{ year}^{-1}$ from the pre-industrial condition. Both experiments are integrated without any flux-correction for 100 years and 90 years, respectively.

The transports induced by STCs and TCs both in hAmO and hAhO are decreased during the course of global warming (Fig.5). Difference of the STC transport between the control and global warming experiments in hAmO and hAhO is almost the same, although difference of the TC transport is larger in hAhO than in hAmO. A main forcing for the STCs and TCs is the Trades, and it is also weakened to the course of global warming. The weakening of the Trades is not largely different in between hAmO and hAhO, but the response of TCs to the weakening Trades is largely different. Therefore, the difference of the TC's slowdown is likely to be caused by the difference in the ocean model resolution.

The slowdown of STCs is linked to the warming in the tropical Pacific. In the global warming experiments, enhanced rise of SST in the tropical Pacific is captured, and it is larger in hAhO than in hAmO. The slowdown of STCs in the both model is not largely different. Therefore, the SST rise is attributable to the different responses of the TCs to changes of zonal winds around the equator.

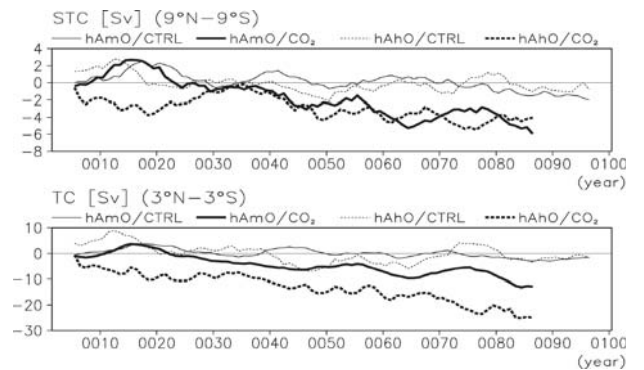


Fig.5 Time series of transports convergence induced by STCs (upper panel) and TCs (lower panel) in the Pacific for each experiment (unit $\text{Sv} \equiv 10^6 \text{ m}^3 \text{ s}^{-1}$). Nine-year moving averaged anomalies from the 100-year mean of the corresponding control experiment are shown. The transport convergence is defined by the equatorward volume transport upper 300 m depth between 9°N and 9°S in STC, and between 3°N and 3°S in TC. "CTRL" and "CO₂" in the figure mean the control experiment and global warming experiment, respectively.

f. QBO and gravity wave

The roles of the equatorial-trapped wave and three dimensional propagating gravity waves in driving stratospheric quasi-biennial oscillation (QBO) remain to be clarified. T213L256 AGCM with no gravity wave parameterizations simulates large-scale oscillations with realistic amplitudes in the equatorial atmosphere such as the QBO and SAO. Model outputs with a time interval of 1 hour are analyzed to elucidate relative importance of the internal gravity waves (IGWs) and equatorially-trapped waves (EQWs) to drive the QBO-like oscillation. It is shown that horizontal wind components as well as precipitation and outgoing long wave radiation (OLR) have realistic characteristics in terms of zonal wavenumber versus frequency spectra which clearly shows the existence of convectively-coupled EQWs. These wave signals are separately extracted for further examination following Wheeler and Kiladis (1999). In westerly shear of the QBO, the horizontal distribution of eastward forcing due to each EQW generally corresponds well to that of the convectively coupled EQW appearing in OLR data. On the other hand, it is seen that IGWs are strongly influenced by the vertical wind shear associated with the Walker circulation in the troposphere, which results in different distribution of IGW momentum fluxes between the eastern and western hemisphere. In the westerly shear phase of the QBO-like oscillation, IGWs contribute to 50-70% of the total eastward acceleration. The equatorial Kelvin waves contribute to the largest forcing among EQWs especially around the altitude with a zonal wind of 0 m/s, while the forcing due to $n=0, 1, 2$ eastward-propagating EQWs becomes comparable to that of Kelvin waves at higher altitudes. It is interesting that the distribution of the wave forcing is not zonally uniform and is different depending on the wave types.

g. Reproduction of the 20th century climate

Comparing the historical temperature changes between observations and dynamical models aiming at reproducing the 20th century climate (Fig.6), the models with volcanic forcing agree better with the observations than those without the forcing. The study also reveals that recent ocean cooling is artificial rather than natural signal since the models can not repli-

cate such a rapid cooling involved in the observations. Subsequently to this study, we developed a scheme of the XBT bias correction. With this correction, eliminating positive biases in XBT data, we found that global warming trends of ocean heat content were overestimated in the previous temperature analyses. Other projects have been in progress in this FY: improvement of the reproduction of ENSO in the CCSR/NIES/FRCGC coupled model, coupled-model data assimilation experiments with several assimilation scheme, development of an EnKF data assimilation scheme, and a model-output analysis for decadal climate changes.

h. Effect of carbon cycles on climate change during the glacial-interglacial cycles

Ancient air trapped in Antarctic ice cores shows periodic variations of atmospheric CO_2 concentration, $p\text{CO}_2$, during the glacial-interglacial cycles. For example, at the Last Glacial Maximum (LGM), $p\text{CO}_2$ was 180-200 ppm which is roughly 80-100 lower than the pre-anthropogenic value. Although it is generally considered that the ocean would have played an important role in the variations of $p\text{CO}_2$, the

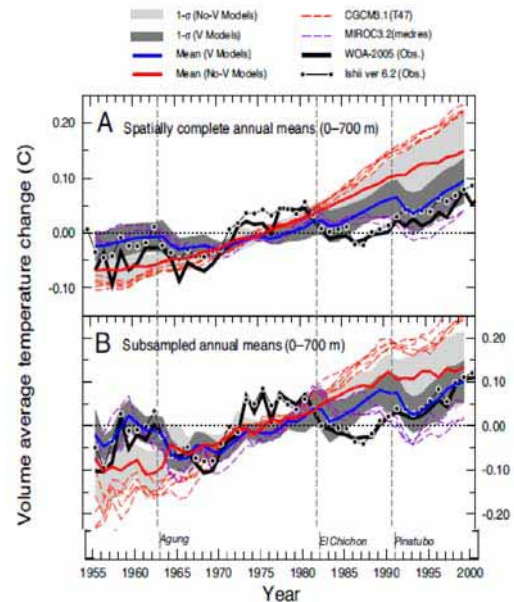


Fig.6 Simulated and observed changes in volume-averaged temperature of the top 700m (A and B) of the global ocean. Model results are from simulations of 20th century climate change performed with two atmosphere/ocean general circulation models: MIROC3.2 (medres) and CGCM3.1 (T47). Observations are from the WOA-2005 data set and the ISHII6.2 data set. The ISHII6.2 data are available for 0=700 m only. Results are shown for both spatially complete temperatures (A) and temperatures subsampled with the WOA-2005 coverage mask (B). The ensemble means of multimodels with and without volcanic forcing (V and No-V models) are also plotted.

mechanism for the variations is still unclear. We've performed some numerical experiments by using an ocean general circulation model (GCM) coupled with biogeochemical processes to evaluate quantitatively the effects of changes in various conditions upon an oceanic carbon cycle and the atmospheric CO₂ concentration.

We have investigated the effect of various changes in physical conditions of ocean (the circulation field, temperature, salinity, and the sea-ice extent) on $p\text{CO}_2$ by numerical experiments. We consider five model ocean physical fields which are based on reproduction by an atmosphere-ocean coupled general circulation model (MIROC3.2). We found that, if a LGM physical ocean field reproduced by MIROC3.2 was assumed, $p\text{CO}_2$ was lowered by ~30 ppm compared to the interglacial value. Most of the 30 ppm reduction can be explained by higher solubility of CO₂ into the ocean due to the glacial lower sea-surface temperature. In particular, the reduction in sea-surface temperature in the North Atlantic had a greatest effect. On the other hand, the effect of change in the circulation was small. This would be because the variation in physical CO₂ transport to the deep ocean and biological counterpart induced by the circulation change would offset each other. We also found that the effect of sea-ice expansion in the Southern Ocean was trivial resulting in only several ppm reduction in $p\text{CO}_2$. Furthermore, if we assumed other model ocean physical fields, the effect of the solubility change was still dominant. We also investigated the effect of biogeochemical changes in the ocean on $p\text{CO}_2$. We focused on the possible variations in chemical composition of the ocean induced by the changes in the sea level and in the terrestrial biosphere. We suggested some defects in a previous study in which the effect of changes in whole-ocean nutrient inventory was examined. We made calculations using our GCM in more appropriate experimental conditions considering properly the variations in mean DIC concentration and in mean alkalinity concentration in the ocean. We found that $p\text{CO}_2$ might be increased as a result of the chemical change contrary to the previous results.

(6) Global Environment Modeling Research Program

The mission of our Program is to develop advanced climate models that have a capability to explore new arena of climate simulations by fully utilizing the Earth Simulator, and has been conducted by the following three groups:

- Next-Generation Model Development Group aims to develop an atmospheric general circulation model (AGCM) treating meso-scale convective system explicitly, and an ocean general circulation model (OGCM) resolving meso-scale ocean eddies.
- Integrated Earth System Model Development Group aims to develop an integrated Earth system model (ESM) including physical climate processes, biogeochemical processes and dynamical processes. The development of the ESM has been supported by the Kyousei-Project (2002-2006) and Kakushin-Program (2007-2011) funded by the Ministry of Education, Culture, Sports, Science and Technology (MEXT).
- Ocean Data Assimilation Research Group aims to develop a four-dimensional variational (4D-VAR) data assimilation system. The Group developed a 4D-VAR assimilation system under the Kyousei-Project. Now the Group participates in the Kakushin-Program aiming at the near future prediction up to about 2030.

The main achievements of each group during FY2007 are summarized below.

Research Results

1) Next-Generation Model Development Group

a. Development of a global cloud resolving atmospheric model

We developed a global nonhydrostatic model, NICAM (Nonhydrostatic ICosahedral Atmospheric Model), which is aimed to resolve deep convective circulations by covering the globe with a few km mesh interval. We expected that NICAM will simulate more realistic behaviors of cloud systems especially over the tropics, since it does not use cumulus parameterization, which is one of the ambiguous factors of current atmospheric general circulation models (AGCMs). In the fiscal year 2007, we succeeded in realistically simulating the Madden-Julian Oscillation (MJO) event with its inner struc-

ture of cloud systems by global cloud resolving simulations. We further conducted relatively longer integration for 5-months seasonal march experiment and explored time variation of tropical disturbances and tropical cyclogenesis. Further, cloud properties simulated by NICAM are examined in terms of both of low level and high-level clouds.

It is known that current general circulation models do not simulate behaviors of MJO very well. We performed global cloud-resolving simulations for an MJO event occurred in December, 2006. The 7km-mesh integration is started at 15 Dec. 2006 and integrated for one-month. The result is shown in Figure1. This shows cloud variation along the equatorial domain over one month and compares with that of the satellite observation. We reproduced the large-scale organized structure of cloud systems, its eastward propagation, and fine scale inner structure, similarly seen in the observed field. The MJO behaviors over the marintime continent region are also realistically simulated. From this series of the experiments, we found the importance of the westward propagating waves with about 5 days periodicity; the cloud systems of MJO jump over the New Guinea island at the time when the westward propagating waves reach this region from the east of the Pacific. This mechanism is clarified for the first time by the km-mesh global model, which includes the detailed orography, appropriate and natural triggering mechanism of deep convection, and interaction between large-scale circulations and deep convection. This result is published in the Science journal, and appealed the performance of NICAM to the world. We further simulate periodicity of MJO and its role on tropical cyclogenesis by extending integration for 3-5 months.

Different from current general circulation models, the global cloud-resolving model (GCRM) uses explicit cloud microphysics schemes. Thus, it is expected that the climate sensitivity associated with global warming is more physically explained by GCRM. We obtain climatological fields of NICAM based on perpetual July condition experiments, and further performed a warmer condition experiment by increasing the sea-surface temperature by 2K to evaluate climate sensitivity. The result shows that high-cloud cover increases in the warmer condition and the longwave cloud radiative forcing

increases; this tendency is opposite to the results from current general circulation models. We are now studying the robustness of this result by exploring sensitivities of parameters used in cloud microphysics schemes and others.

According to the recent analysis of climate models, there are large ambiguity in simulating low clouds over the subtropical oceans near California and Peru. Improvement of low clouds properties is one of the urgent tasks of climate modeling. Since the grid size of GCRM is a few kilometer, GCRM also requires boundary layer schemes similar to the current climate models, instead of directly resolving boundary layer circulations, and it has been unknown whether GCRM will simulate the low cloud properties well. We therefore tried to improve the low clouds by implementing a boundary layer scheme by Nakanish and Niino, which was newly developed under Kyosei-project. Figure2 shows the low cloud amount simulated by NICAM. This shows that geographical distributions of low clouds over the oceans near California and Peru are reproduced. This indicates that GCRM has better performance in simulating low clouds in addition to deep clouds. We will continue improvement of physical processes, especially for cloud microphysics and boundary layer schemes.

Researches of the next-generation atmospheric modeling group are involved in many cross-cutting programs. A program of JST/CREST (Japan Science and Technology Agency/Core Research for Evolutional Science and Technology) was awarded in 2005; "Global Cloud Resolving Model Simulations toward Numerical Weather Forecasting in the Tropics". Another new research project is also awarded by Innovative

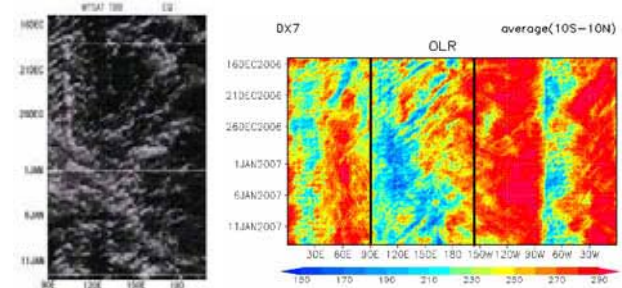


Fig.1 A Madden-Julian Oscillation simulated by the global cloud-resolving model, NICAM. Right: Simulated Hovmöller diagram of the outgoing longwave radiation (OLR) averaged over the equator belt (10S-10N). The 7km-mesh NICAM integration for 1 month with the initial condition at 15 Dec., 2006. Left: Hovmöller diagram of TBB (black body temperature) on the equator observed by the geo-stationary satellite MTSAT-1R.

program of climate change projection for the 21th century, which start from the fiscal year 2007;"Improvement of cloud-precipitation systems for climate simulations using a global cloud-resolving model". A joint program with IPRC based on ANNEX1 started in the fiscal year 2007. From the beginning stage, we have participated in the activities of CMMAP (Center for Multi-scale Modeling of Atmospheric Processes) , which is oriented by Colorado State University (CSU) , USA. Dr. Miura in our group is now visiting CSU. Through the above mentioned programs, researches using NICAM are collaborating with many research groups, including other programs of FRCGC, centers of JAMSTEC, especially IORGC, Center for Climate System Research (CCSR) of Univ. of Tokyo, MRI, and HyARC of Univ. of Nagoya. We organized an international workshop on next-generation modeling at Kyoto, Dec. 2007, in which about 20 people were invited. We already distributed the numerical data of NICAM to many research groups. In March, 2008, we held a NICAM data users workshop, in which about 50 people participated in. Our numerical data are open to public, and we also encourage more people to join the development and use of NICAM.

b. Development of an eddy resolving ocean model

An advanced ocean model which can reproduce ocean circulations with high accuracy has been developed. The model simulates ocean circulations with mesoscale eddies explicitly resolved by fully utilizing the Earth Simulator. The obtained results are employed to improve an ocean model which is currently used for global warming experiments.

In this year, we have started a simulation of the Agulhas current region by using the developed ocean model. Figure3 shows the strength of the surface current obtained by the model. The Agulhas rings generated in the east coast of Africa are well reproduced. In order to study effect of eddies to mass transport, artificial passive tracer is released in the south-western Indian ocean. The tracer is advected by the Agulhas Current and then flows into the South Atlantic Ocean. Figure4 shows tracer distribution on $\sigma_\theta=27.1$ surface layer. This figure shows that water from the Indian Ocean is trapped by eddies. This feature is not reproduced in the coarse resolution simulation of 40 km horizontal grid size.

We also perform an eddy resolving simulation in the Southern Ocean to investigate interactions between eddy and

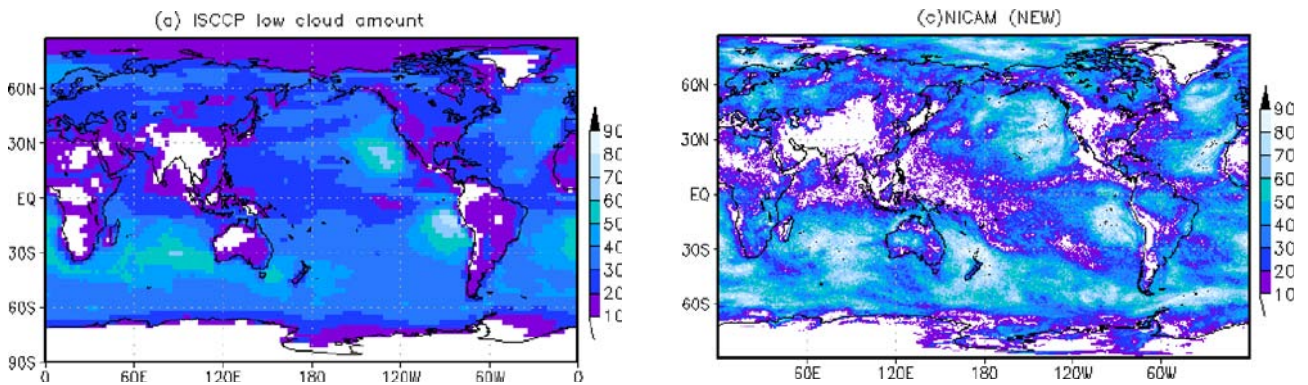


Fig.2 Left: Observed low cloud amounts by ISCCP in July 2004. Right: Simulated low cloud amounts by NICAM, 14km-mesh experiment.

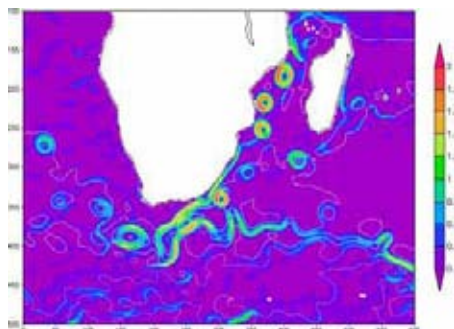


Fig.3 Surface velocity strength (m s⁻¹) .

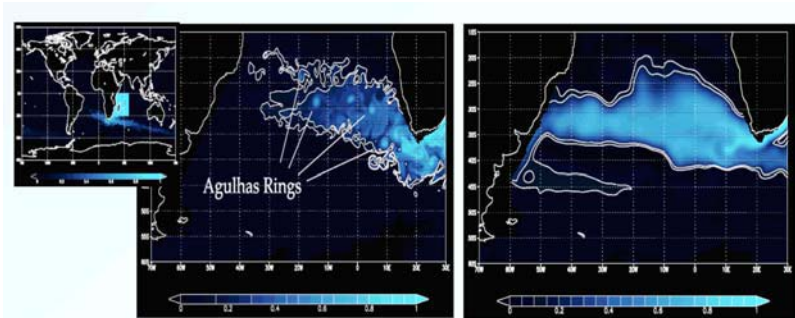


Fig.4 Passive tracer density on $\sigma_\theta=27.1$ isopycnal surface after 7-year integration for 15-km simulation (left) and 40-km simulation. Contour indicates tracer density 0.1 and 0.2.

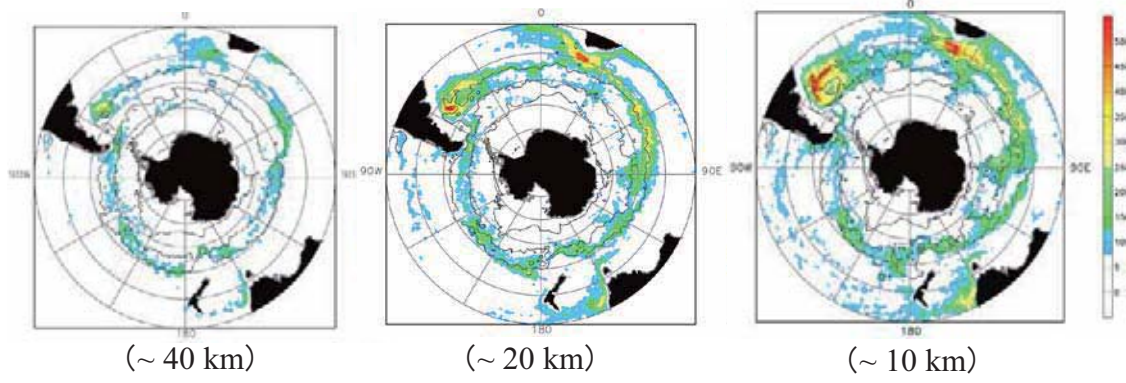


Fig.5 The sea surface height variability in centimeters. The solid line shows streamline through Drake Passage.

large scale ocean circulation. In this region, mesoscale eddies may play important role in the formation of the intermediate water. Three horizontal resolutions of 10, 20, and 40 km are used for this investigation. Figure5 shows the SSH variability evaluated as the root-mean-square of SSH. This variability represents the strength of eddy activities. For the 40 km case, the SSH variability is relatively weak. Since the deformation radius is about 20 km at a latitude 54S, it seems that mesoscale eddies are not resolved well. For the 20 km case, the variability increases significantly from the 40 km case. The variability is high in the equatorward flank of the ACC, especially on the northern boundary of the ACC. The variability is large in the Argentine Basin and the Agulhas Retroflection region. For the 10 km case, the intensity of the variability reaches about 50 cm in the Brazil-Malvinas Current confluence and the Agulhas Retroflection region. Figure6 shows the vertical section of salinity at 30 W. For the 40 km case, low salinity water is not transported downward along the $\sigma_0=27.1$ surface. The 34.5 salinity water reaches only about 400 m depth. For the 20 km case, the low salinity water is transported downward deeper

than the 40 km case and 34.5 salinity water spreads along the $\sigma_0=27.1$ surface up to about 500 m depth. For the 10 km case, the 34.5 salinity water, which is subducted along the $\sigma_0=27.1$ surface, reaches more than 1400 m depth. Although the spreading of the salinity is still somewhat weak even for the 10 km case compared with the climatology salinity distribution, it is much better than the low resolution cases.

2) Development of an Integrated Earth System Model for Predication of Global Environmental Changes

a. Long-term climate change projection with an integrated earth system model

Using the integrated earth system model, we have calculated future CO₂ emission pathways allowable to achieve CO₂ stabilization at 550 ppm and 1000 ppm around year 2300 (i.e., SP550 and SP1000). It has been confirmed that, when one takes into consideration the possible feedback between climate and carbon cycle, necessary reduction of CO₂ emission is severer than it is when one does not (Fig.7). It turned out that the terrestrial carbon cycle saturates rather quickly and cannot act

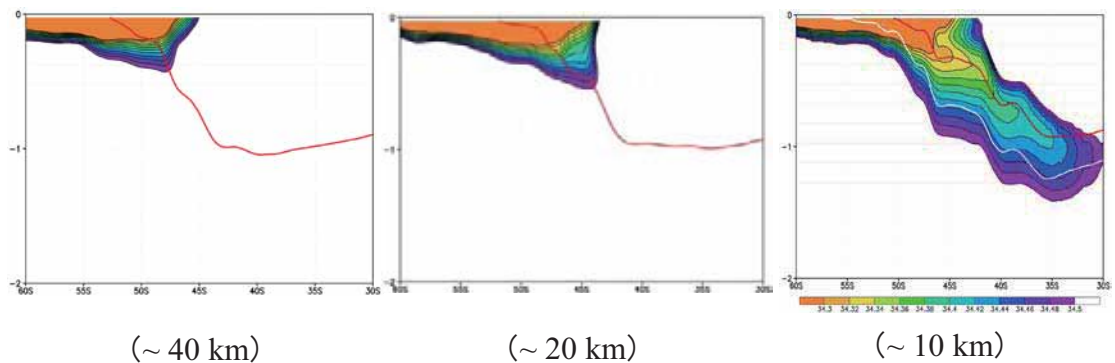


Fig.6 Vertical section of salinity at 30 W. The vertical axis indicates depth in kilometers. The red line denotes $\sigma_0=27.1$ isopycnal.

as a sustained sink on the multi-centennial time scale. The oceanic sink, on the other hand, remains to be a sink throughout the integration period due to its long characteristic time scale. Also, by strengthening relationship with the impact assessment group of National Institute for Environmental Studies, a new series of experiments has been started under a scenario to halve CO₂ emission by 2050. The result suggests an intriguing implication that, under such a low emission scenario, relative importance of aerosol forcing increases compared to higher emission scenarios such as SRES A2.

We are also analyzing the simulation results obtained under the former "Kyosei" project in order to obtain perceptions on the global carbon cycle. Specifically, to identify characteristic variations in the simulation results, an analysis has been made on inter-annual variations of CO₂ flux in the simulation where no anthropogenic CO₂ emission was imposed. The analysis shows that SST anomaly pattern with its maximum in the eastern equatorial Pacific is dominant when the CO₂ flux anomaly from the ocean to the atmosphere is negative. On the other hand, SST anomaly has its maximum in the central equatorial Pacific when the CO₂ flux anomaly from the land to the atmosphere is positive. Thus, ocean-to-atmosphere and land-to-atmosphere CO₂ flux anomaly are associated with two different climate modes, respectively. These flux anomalies may have the same or the opposite sign depending on the phase of the two climate modes.

At present, the international community is working on revision of input datasets for the next-round global warming projection experiments. It is expected that our group contributes to this activity though preparation of GHG emission datasets with explicit spatial distribution; that is, using the terrestrial ecosystem model VISIT, which is capable of dealing with carbon cycle and other chemical species released by vegetation, aerosol emissions originating from natural forest fires have been calculated for 1900 - 2100. Model results around 2000 are compared to satellite-based data, based on which possibilities to improve the model have been discussed. We advocate use of emission data for aerosol and chemical species thus calculated, although it is yet to be determined whether such data are officially used for the next-round global warming projection experiments.

iments.

Improvements for the integrated earth system model (ESM) itself are progressing. As for stratospheric chemistry, prospect is that the incorporation of halogen compounds and PSCs will be completed in the first half of FY2008. Incorporation of short-wave ultraviolet parameterization has been already completed, which enable the ESM to represent the impact of solar variation on the dynamics of stratosphere. Collaborations are going on with other FRCGC programs (ECRP and GWRP), Center for Climate System Research, Univ. of Tokyo, and National Institute for Environmental Studies for improvements of physical parameterizations and the ocean model, and incorporation of the dynamic vegetation model (SEIB-DGVM). Our group is mainly in charge of overall scheduling of model development, merging individual improvements into a single code, re-installation of ocean carbon cycle model into the improved ocean circulation model, and running preliminary experiments with the improved merged code on the Earth Simulator. In addition, development and improvements of the ESM during the former "Kyousei" project have been documented and published in the Journal of the Earth Simulator. Furthermore, a WWW-based system called Wiki has been established in order to facilitate information exchange on model development.

b. Uncertainty estimation for long-term climate change projection with a hierarchy of models

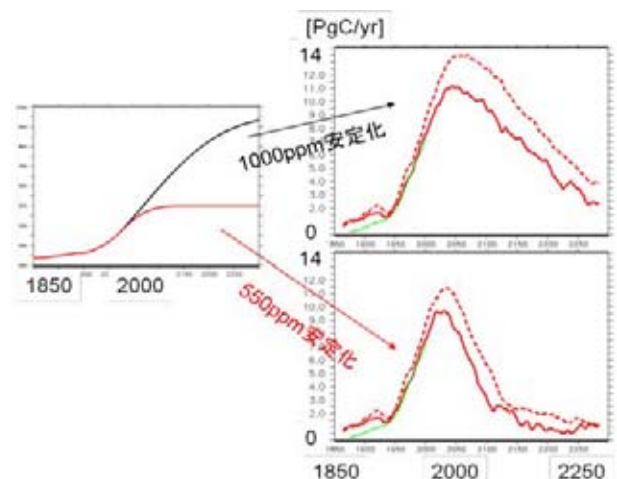


Fig.7 CO₂ emission pathways to achieve stabilization of CO₂ concentration calculated by the integrated earth system model. Solid lines are for runs with carbon cycle feedback and dashed lines without one.

Progress has been made for the development of MIROC-lite, our earth system model with intermediate complexity (EMIC). After some manual model tuning, results of MIROC-lite are compared with observations and also outputs of other EMICs (Uvic and GENIE) and a GCM (MIROC with the intermediate resolution). It is shown that MIROC-lite is now capable of reproducing realistic surface temperature distribution and deep water formation. A more sophisticated model tuning method using the ensemble Kalman filter is being developed. We are collaborating with Global Warming Research Program for, among other things, improvement of statistical methods for sorting out numerous experiments that will be conducted with MIROC-lite. Interesting results are obtained also for the uncertainty estimation of GCM-based global warming projection, such as dependence of climate sensitivity on the background climate (i.e., present climate and Last Glacial Maximum), and the significantly higher climate sensitivity when one tunes an AGCM coupled with a slab-ocean with a constraint that Q-

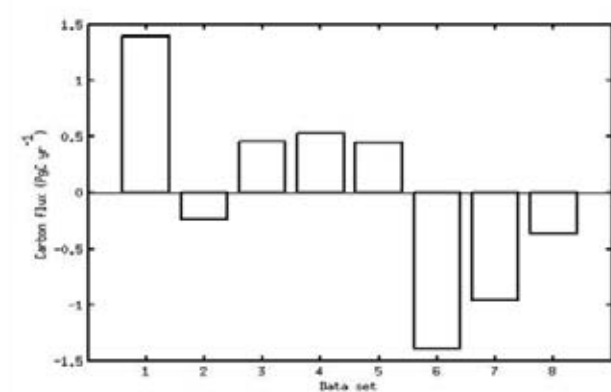


Fig.8 differences among datasets in net carbon uptake by land ecosystem for 1990's. Negative values mean net uptake by land ecosystem. See Table 1 for the datasets represented by numbers.

Table 1 Datasets used for estimating net carbon budget.

Number	Study	Resolution	Method	LUC
1	Houghton [2006]	Region/country	Book-keeping	LUC1
2	UNFCCC [2000]	Country	Inventory	National inventory
3	Olivier and Berdowski [2001]	Country	Inventory	FAO
4	Hurt et al. [2006/2002(USA)]	Country/1°(USA)	Inventory/process	National statistics
5	de Campos et al. [2006]	Country	Book-keeping	LUC2
6	Kato et al. [2007]	T42 (2.8° × 2.8°)	Process model	LUC3
7	Jain and Yang [2005]	0.5° × 0.5°	Process model	SAGE
8	Ito et al. [2008]	Region/country	Consolidated data	N.A.

Flux (air-sea heat exchange due to flux adjustment) approaches zero when integrated over the globe.

It is anticipated that, in the next round of the global warming projection, data for carbon emission from land-use change are also used to force models. Uncertainty estimation is performed for such datasets. The result shows that even the sign of net carbon budget for 1990's including land-use change and forest growth is dependent on the dataset, and that one of the causes for the discrepancy is non-unified scheme and terminology used for creation of the datasets (Fig.8, Table 1). This result has been published as a contribution to MATCH, an international project on global warming.

3) Development of Data Assimilation System

Accurate descriptions and forecasts of climate variabilities are of great importance to a wide cross section of society (Palmer et al., 2004; Mochizuki et al., 2007). Toward the better representation of the dynamical states of climate processes, recent studies have focused on an optimal synthesis of observational data and model results with the assimilation methods, since observational data available for the study are still too sparse in space and time to resolve the important energetics of climate variations on one hand and on the other hand numerical models are not enough to accurately quantify actual climate states due to the well-known uncertainties arising from initial conditions, sub-grid scale parameterization and so on (e.g., Fukumori and Wunsch, 1991, Stammer et al., 1998). In fact, assimilation studies using ocean general circulation models (GCMs) or atmospheric GCMs have produced many fruitful outcomes such as the construction of important reanalysis

datasets suitable for practical use in the identification and prediction of oceanic or atmospheric phenomena (e.g., Kalnay, 2003). However, the present use of data assimilation and its products are still limited. For this reason, we have attempted to enhance practical applications of data assimilation products to important aspects of scientific and/or societal problems. Here we present some results of the important applications to interdisciplinary scientific researches.

a. Enhanced coupled waves associated with anomalous El Niño development

Using reanalysis fields obtained from our 4D-VAR ocean atmosphere coupled data assimilation experiments in the 1990s, we have diagnosed the air-sea coupled processes associated with anomalous SST increase in the central to eastern equatorial Pacific, focusing on the evolution of the historically strongest 1997-1998 El Niño event. Figure 9 shows that the onset of the 1997-1998 El Niño was triggered by westerly wind bursts (WWBs) in the western equatorial Pacific in February-March 1997 and the resulting downwelling Kelvin waves propagated eastward accompanied by positive sea surface temperature anomalies (SSTAs) and atmospheric fluctuations as reported by McPhaden (1999). When the coupled waves reached the central to eastern equatorial region, where larger horizontal gradients in the thermocline depth existed, they rapidly assumed large-amplitudes and were then capable of causing the strong El Niño. Such waves actually propagate at lower speeds (50-60 cm/s) than free waves (180-200 cm/s), consistent with the dynamic nature of growing coupled modes. The coupled processes reproduced here are such that large SSTAs generate stationary twin Rossby waves off the equator to the west (Matsuno, 1966) by nonlinearly enhanced latent heat release. Equatorial westerly wind anomalies between the twin Rossby waves induce enhanced eastward wind stress anomalies, which strengthen the eastward oceanic surface flow, the depression of the thermocline, and hence the SSTAs. The coupled structure and the propagation speed of the amplified coupled waves are consistent with the unstable mode in the intermediate regime of coupled Kelvin and Rossby waves shown analytically by Yamagata (1985) and Hirst (type III, 1986).

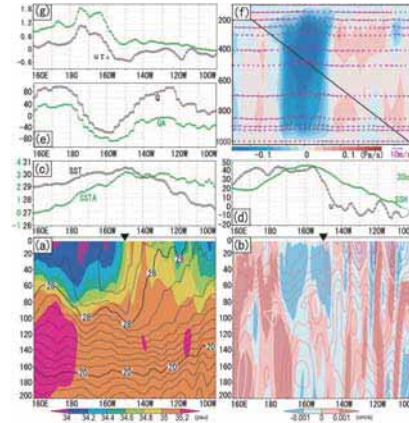


Fig.9 Zonal distributions during the first 10 days of November 1997 of (a) salinity (shaded) and temperature (contours in °C), (b) vertical (shaded) and zonal velocity (contours with 10 cm/s intervals; red, white, and blue denotes eastward, zero, and westward, respectively), (c) SST (black) and SSTA (green; in °C), (d) oceanic surface zonal velocity (black; in cm/s) and sea-surface height (green; SSH), (e) surface downward net heat flux (black; in W/m²) and its anomaly (green), (f) atmospheric p-velocity (shaded) and zonal velocity (horizontal components of arrows) field, and (g) power transfer from zonal wind stress to the upper 100 m ocean and its anomaly (black and green; in W/m²). These values are averaged over 5°S-5°N except SSH, which is averaged over 2°S-2°N. SST maximum positions are indicated by black triangles in (a) and (b).

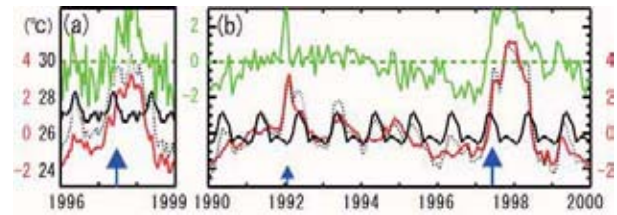


Fig.10 Time series of the climatological seasonal march of SST (black), total SST (black dotted), SSTA (red), and zonal wind stress anomaly (green) averaged over 160°W-140°W and 2°S-2°N (a) from our CDA product and (b) from the ocean reanalysis dataset (Masuda et al., 2006).

Our analysis reveals the important role played by seasonal SST increase in the central to eastern equatorial region in the amplification of air-sea coupling in the 1997-1998 El Niño event as demonstrated in Figure 10, which augments the effects of sharp thermocline tilt. The annual march of climatological SST has its peak in boreal summer in this region. Anomalous latent heat release by interplay between the incident Kelvin waves linked to warm SST and the seasonal rise of SST most likely works to develop unstable coupled waves. The amplified coupled waves travel eastward with relatively little loss of energy, and abruptly cease to the east of 130°W where mean SST rapidly decreases. Note that the occurrence of such interactions around the central to eastern equatorial region is favorable to

longer and hence more enhanced air-sea coupling than that suggested by Neelin et al. (2000), which develops in the eastern region. Moreover, the fact that La Niña s do not show a similar phase-locking behavior is likely explained by the absence of a nonlinear influence from the seasonal cycle on the coupling instability.

In terms of the forecasting of El Niño events in the 1990s, we have made the ensemble prediction using the reanalysis dataset obtained by the coupled data assimilation experiment. Figure 11 displays the time series of Niño 3.4 SST values in the reanalysis field obtained by our assimilation experiment, which exhibit extremely realistic time-trajectories. Using this reanalysis field as the initial condition, we have attempted the ensemble prediction. The result (Fig. 12) suggests that the longer predictability over 1-year-lead-time is realized for all the El Niño events in the 1990s. These results underline that our 4D-VAR coupled data assimilation has more ability to create important information on climate variabilities and longer forecast potential for the S-I phenomena, although further investigations are required in order to reveal the details of individual events.

b. Application to water resources and fishery stock Assessment

In parallel with the ocean-oriented climate analysis using

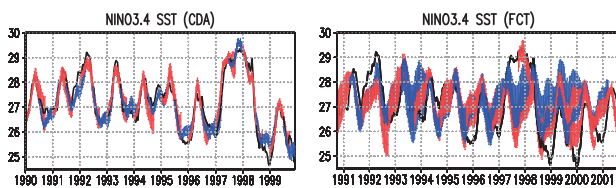


Fig.11 (a) Reproduced NINO3.4 SST by CDA system and (b) predicted time change of NINO3.4 SST.

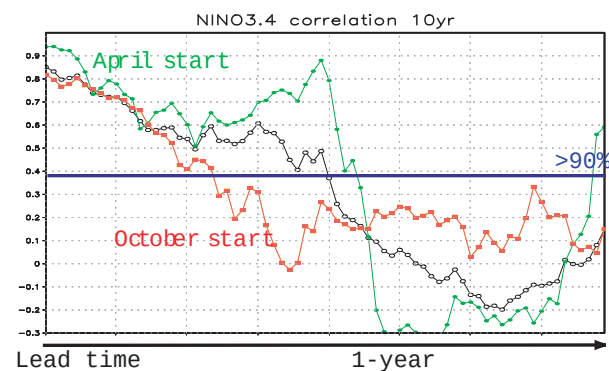


Fig.12 NINO3.4 SST ACC for the 1990s prediction experiment

the high-quality reanalysis datasets obtained by our 4D-VAR reanalysis experiments, we have attempted to make high impact applications that warrant social benefits such as water resource management and fishery stock assessment as below. In terms of the water resource management, the source distribution and the transport process of individual rainfall events are able to be identified by the adjoint sensitivity experiment using the 4D-VAR system. As a result, evaporative sources for the typical events of heavy rainfall at some target areas are successfully traced back to their origins as observed (not shown). This gives us important information to construct the flood monitoring system that contributes to the reduction of regional damages for human activities and hence the effective risk management. Also, the left bottom panel of Figure 13 displays an example of the estimated evaporative source distribution associated with Asian summer monsoon rainfalls at specified areas of the Indochina Peninsula, through which we can detect the tempo-

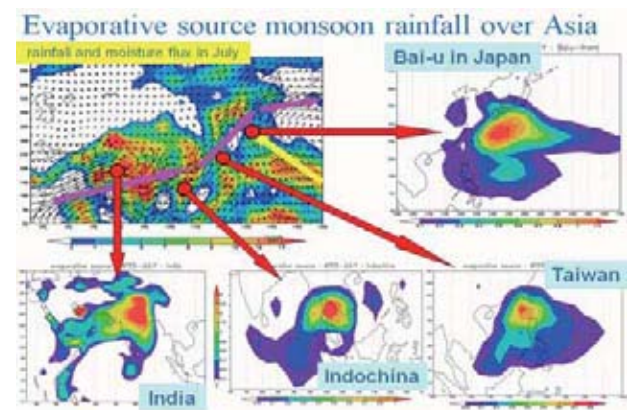


Fig.13 Evaporative source distribution of rainfall over Asia derived from 4D-VAR adjoint sensitivity experiment.

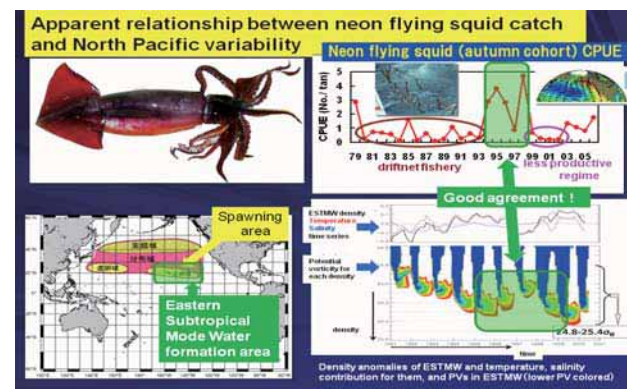


Fig.14 Relationship between the interannual variation of neon flying squid CPUE in North Pacific and that of eastern subtropical mode water formation.

spatial structures of the "key phenomenon" causing the flood and drought at each area. Furthermore, the mechanism of water cycle modulations by ENSO could be elucidated by applying the 4D-VAR method to the time series of the anomalies.

Previous studies show that an accurate ocean state estimation is one of the most important factors for fishery stock assessment because almost all kinds of fishes adapt their life cycle to the ocean environment around their living field. In case of neon flying squids in the North Pacific (right panel of Fig. 14), the close relationship is found between the interannual variation of the catch per unit effort (CPUE) of the autumn cohort in the late 1990s and that of eastern subtropical mode water formation where is the main spawning area. On the other hand, the decadal ocean regime shift has a great influence on squid catch after 1999. These results suggest that the survival of young squids could be strongly affected by the variation in the time-varying subtropical upper ocean structure. We will make further analysis to gain more knowledge about such relationships by collaboration with fishery scientists on the 4D-VAR DA research platform.

c. A near-term global warming ensemble prediction experiment

As a first step toward more reliable global warming projection, we focus on the reduction of forecast errors for low frequency variabilities by developing a data assimilation technique. In doing so, we combined a pre-processing of observational data (nearly 5-year averaging) and the IAU method for selection and initialization of low frequency components from noisy observational data. Figure15a displays both the observed sea surface temperature (SST; red) associated with the Pacific decadal oscillation (PDO) in the latter half of 20 century and the reproduced one (green) by our data assimilation. In addition, the result with no assimilation is denoted by a green curve. It is visible that the reproduced PDO reflects the familiar gross features of the observed one, much better than that with no assimilation. Using this analysis field as the initial condition, we performed near-term ensemble forecasts starting at 3 different years (Fig.15b). The error bars represent the ensemble spread and hence is considered to indicate uncertainty of the forecast result. The time trajectory of the ensemble mean well

follows the observed time change of low frequency variability of SST with moderate ensemble spreads. This fact suggests that our method is useful in improving near-term global warming prediction of climate variability.

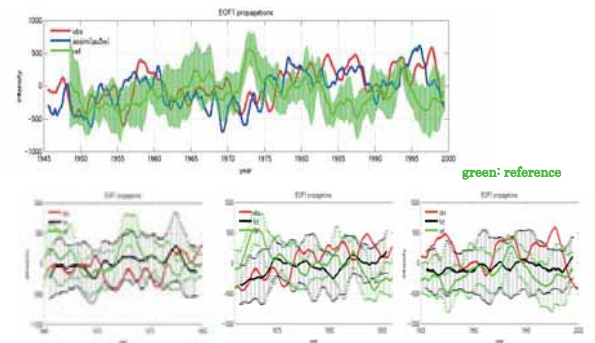


Fig.15 (a) Time series of low frequency variabilities (red: observation, blue: assimilation, black: prediction, and green: reference with no assimilation), and (b) near-term ensemble forecast results (left: starting from 1965, middle: from 1971, and right: from 1985).

Role in Society

1) Next-generation models

Using NICAM by explicitly resolving mesoscale circulations globally, we expect better simulations of convective clouds and precipitation system in the tropics. In particular, we expect that improved simulations of Asian monsoons and the Madden-Julian Oscillations (MJO) will greatly contribute to the weather forecast and its related study in the Asian region including Japan. This possibility is now being investigated in JAMSTEC. The global cloud resolving model which does not use the cumulus parameterization has less uncertainties than the conventional atmospheric general circulation models. Therefore, NICAM may provide more reliable information about climate sensitivity and contribute to a more reliable global warming projection. We thus participate in Kakushin-program, "Innovative program of climate change projection for the 21st century", started in 2007. Following the successful results by our group, it is realized by international climate modeling community that the global cloud-resolving models will be one of the major streams in climate studies in near future. In May 2008, the Modelling Summit is held at ECMWF, Reading, UK to discuss this issue. A similar contribution is expected for the eddy-resolving ocean model through clarifying the physical

processes of mesoscale eddies in the ocean.

The developed ocean model is used to investigate the physical processes of mesoscale eddies. The results of this investigation are expected to improve accuracy of global warming experiments.

2) Integrated Earth system model

The integrated earth system model being developed by our group is a fairly advanced one compared to those by other institute, in that biogeochemistry (particularly atmospheric chemistry) and stratospheric dynamics, in which chemistry contributes to the key processes, are treated in a sophisticated manner.

This type of model that we are developing is expected to play a central role in the next-round of IPCC assessment. Global warming projection performed by the model which we are developing will enhance the presence of Japan in this field. Among the results obtained during FY2007, calculation of allowable CO₂ emission pathways for CO₂ stabilization may be of direct relevance to establishing countermeasures against global warming. Our model can be a basis for Japan to provide sound proposals supported by scientific perceptions in, e.g., international negotiations for CO₂ emission reduction. It is, in addition, important to grasp uncertainties contained in projections, especially when the projections are applied to impact assessment for primary industry and social infrastructures.

3) Data assimilation system

With an aim to make a further use of ocean and coupled data assimilation systems toward important scientific and societal problems, we have attempted to build up a comprehensive and coordinated datasets capable of providing high level impacts on a wide-cross section of society. For example, the integrated dataset works to strengthen our understanding of the dynamic nature of seasonal to internal climate variations such as El Niño events and also to provide better initialization leading to the enhanced predictability of S-I phenomena in the 1990s when a variety of El Niño events took place. In case of the application to fishery stock assessment, close relationship is identified in the late 1990s, for example, between the interannual variation of the catch per unit effort of neon flying squids in

autumn and that of the eastern subtropical mode water formation. These results using the reanalysis products underline that our ocean and coupled data assimilation system has more ability in practical use than earlier systems and, further, has the potential to create an interesting new prospect of ocean-related processes.

1.1.3 Research on dynamics of the inside of the Earth

(1) Geophysical tomography research group

1) Seismic imaging of the South Pacific superplume

A variety of geological and geophysical phenomena suggest a large-scale (the order of 1000 km) mantle upwelling beneath the South Pacific, the South Pacific superplume, while the geometry, temperature, and composition of the superplume remain controversial. To better constrain the superplume, we deployed temporary broadband seismographs on oceanic islands and seafloor in the South Pacific, where seismic stations have been sparse. The seismic image obtained from the new seismic data indicates the superplume is located from the bottom of the mantle to 1000 km depth and narrow plumes (the order of 100 km) are present above it (Fig. 1). The obtained geometry may indicate that the superplume is not only thermal but chemically distinct upwelling.

2) Topography on the mantle discontinuities in and around the stagnant slab beneath the Philippine Sea

We have deployed BBOBS and OBEM in the Philippine Sea and western Pacific to obtain geophysical image of the stagnant slab beneath the Philippine Sea. We employed a receiver function method for broadband data from 2005 to 2007 to determine depths of the 410-km and 660-km discontinuities (Fig. 2). The 660-km discontinuity is deepened to be 695 km in the stagnant slab, which is substantially deeper than the global average (660 km). It is 670 km in the surrounding area.

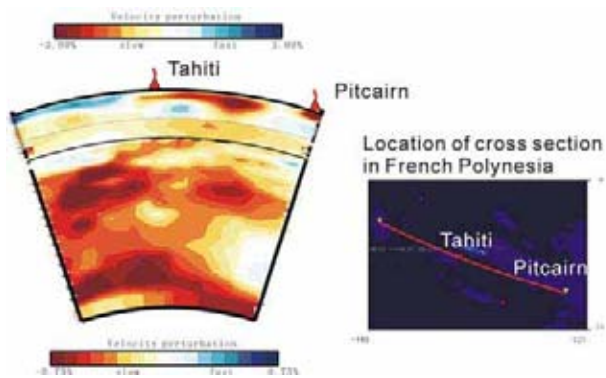


Fig.1 A seismic cross section passing the Tahiti and Pitcairn hot spots. S-velocity variations are shown for the upper mantle and mantle transition zone and P-velocities are shown for the lower mantle. Red and blue colors denote slower and faster velocities than the global standard, respectively.

Comparison with mineral physics data, we can estimate temperatures in the stagnant slab to be 400-500 K colder than in the surrounding area.

(2) Geodynamic Modeling Research Group

1) Numerical simulation of High-Ray number Mantle Convection.

We made systematic research on the patterns and heat transport for the wide range of Rayleigh numbers (Ra) in Earth-like spherical shell geometry. We succeeded in attaining Ra over 10^9 by using the Earth Simulator, which is more than six orders above the critical value. The Ra of the present mantle is estimated to be around 10^7 , and it has been decreasing through

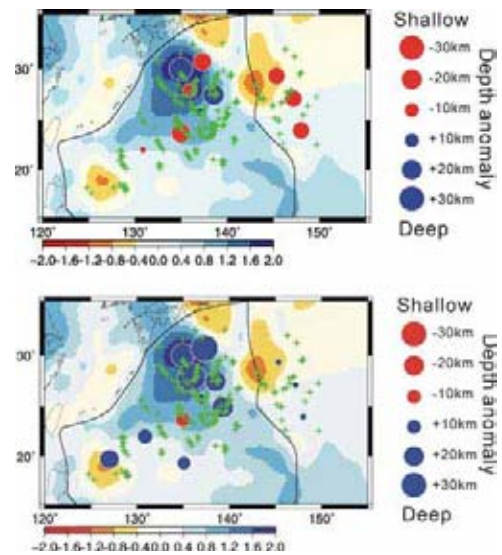


Fig.2 Topography on the 410-km (top) and 660-km (bottom) discontinuities plotted on the seismic stations. Red and blue circles denote shallower and deeper discontinuities than the global standard, respectively. Green pluses are piercing points of Ps converted waves at 660 km depth. Background colors are P-velocity variations at around 660 km depth obtained by a global P-velocity tomography (Obayashi and Fukao, 2006).

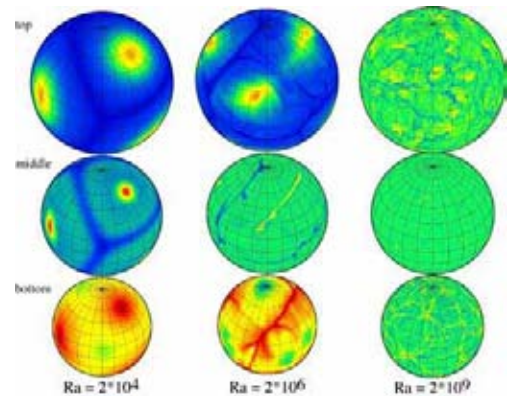


Fig. 2-1 Snapshots of the convection in spherical shell for $Ra = 2 \times 10^4$, 2×10^6 , 2×10^9 . Temperature is shown by color (red=hot, blue=cold). With the increase of Ra, the size of the flow structure gets small and the temperature anomaly at the middle depth becomes weak.

the Earth's history because of the decrease of the heat sources. Our results over 10^9 is sufficient to cover most of the history of mantle convection. The typical wavelength of convection pattern gets shorter with the increase of Ra , and the patterns for high Ra are characterized by the vertical motions of numerous small plumes (Fig. 2-1).

2) Topography and geoid from instantaneous flow calculations in spherical shell: Effects of lateral viscosity variation in the mantle

We have employed instantaneous flow calculations in the three-dimensional spherical shell to investigate effects of lateral viscosity variation (LVV) in the lithosphere and mantle on the long-wavelength geoid anomaly. The density model is constructed by combining the high-resolution tomography model with the subducted slab model based on the seismicity (Yoshida et al., 2007). The global strain-rate model is used for modeling the weak (low viscosity) plate margins in the lithosphere. The LVV in the lower mantle is compiled by using the reasonable relation between the seismic velocity and the viscosity. Our results show that, considering highly viscous slabs in the upper mantle, the observed positive geoid anomaly over the subduction zones is realized only when the viscosity contrast between the reference upper mantle and the lower mantle is around 10^3 , and weak plate margins are imposed in the lithosphere. The LVV in the lower mantle has a large influence on the geoid pattern (Fig. 2-2).

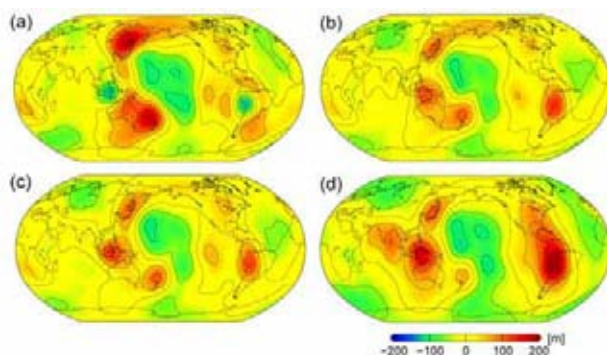


Fig. 2-2 Calculated patterns of geoid anomaly for four cases. The viscosity contrast between the reference upper mantle and the lower mantle is around 10^3 . (a) no weak plate margin (no LVV in the lithosphere), with the viscosity contrast between the subducting slab and upper mantle (R_{slab}) to be 10^4 . (b) same R_{slab} as (a) including weak plate margin. (c) $R_{slab}=10^2$ including weak plate margin. (d) introducing LLV to lower mantle for the case (b). Color scale and contour: red shows positive and blue shows negative geoid anomaly with the contour interval 50 m.

3) Deep Sea Research Group

a. IODP NanTroSEIZE Stage 1 expeditions

During NanTroSEIZE (Nankai Trough Seismogenic Zone Experiments) Stage1A, three IODP (Integrated Ocean Drilling Program) expeditions were successfully completed (Fig. 1). 8 holes were cut to take the transect from the toe of accretionary prism, shallow megasplay section, and to the forearc basin above the updip limit of locked portion of seismogenic fault. Although the interpretation is only preliminary as of this writing, we believe that both the frontal thrusts and shallow megasplay have been active to the present age, contributing to the

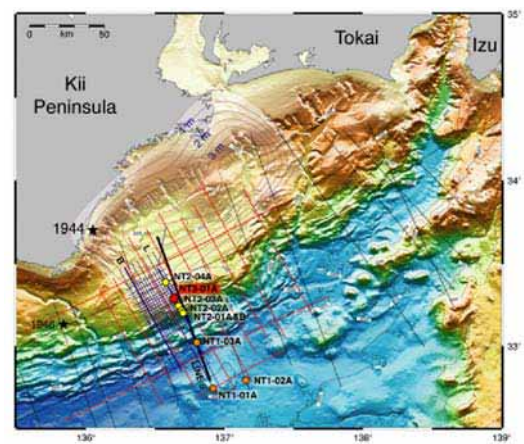


Fig. 1 Bathymetry of Kumano region and NanTroSEIZE drillsites (yellow and red dots).

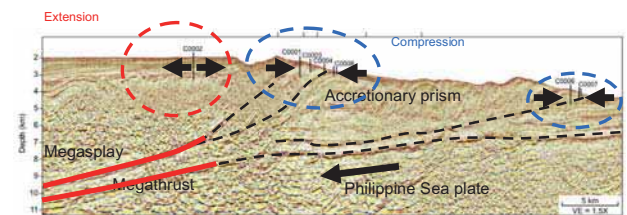


Fig. 2 NanTroSEIZE Stage 1 drillsites(C0001–C0008) and stress orientation direction inferred from LWD borehole breakout images (arrows).

evolution of accretionary prism and seismogenic zone, and to the recent earthquake/tsunami generation (Fig. 2). More studies on the obtained data, as well as the subsequent drilling operations from 2008, will further reveal the characteristics and dynamics of seismogenic behavior in this region.

b. Geophysical measurement and monitoring on the seafloor

In order to understand the behaviour of sub-seafloor faults, seismic activity, landslides, submarine volcanic activity, we

carried out measurements and monitoring of geophysical properties on the seafloor.

An ocean bottom magnetometer (OBM) was successfully connected to the branching instrument at the end of seafloor cable off Toyohashi. Data is being transferred real-time to JAMSTEC Yokohama Institute, as well as being published via website. Near the cable end a temporary resistivity structure survey was made using 9 OBEMs.

As in the previous years, 2 borehole hydrological observatories (ACORKs), installed near the toe of accretionary prism off Muroto, were revisited and data were successfully retrieved. Also, a hydrologic seal was installed at the mouth of ACORK at ODP Hole 808I after 5 years of trials (Fig. 3).

Ultra-high resolution bathymetry and side-scan data were obtained using JAMSTEC AUV "Urushima" in the western Sagami Bay, Kumano-Nada and Mid-Okinawa Trough. Traces of submarine landslides, hydrothermal chimneys and plumes (in the water column) were clearly imaged (Fig. 4).



Fig.3 ACORK head observed during the KY07-18 cruise. (Left) Before installing the seal more than half of ACORK mouth is buried beneath the sediment. (Right) Hydrologic seal was installed.

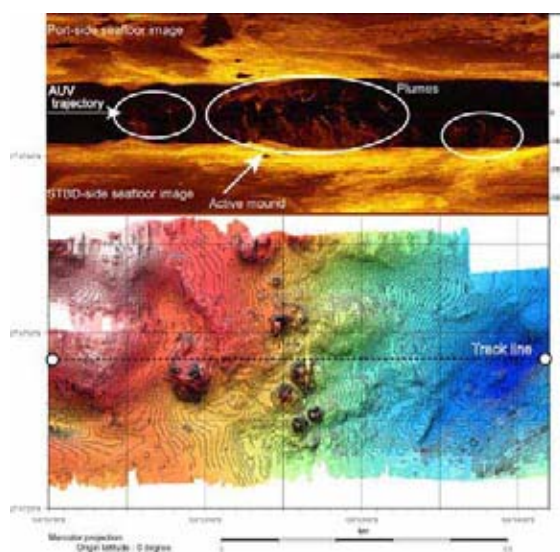


Fig. 4 (Bottom) Ultra-high resolution bathymetry obtained SEABAT installed at URASHIMA, in the Iheya-north hydrothermal area of mid-Okinawa Trough. (Top) Sidescan image in the same area. Hydrothermal plumes are clearly identified in the water column.

c. Progress on the oceanic lithosphere study

Seafloor surveys have been carried out to understand island arc crust and oceanic lithosphere around Japan.

From a petit-spot volcano in the northwestern Pacific ocean, three alkali basalts were newly sampled. The inner structure of petit-spot volcano, outcropped by a horst and graben fault, was carefully observed and mantle xenoliths were sampled.

It was shown that the geochemical diversity, identified in the 14degS EPR giant lava field, could be explained by the melt component of depleted mantle (as a typical source for N-MORB) mixing with an enriched "non-plume" component.

From the Hess Rise in the central Pacific, core samples was taken to the age of 1.6 Ma, and a 100kyr-period was identified in the geomagnetic variation, as well as in the Equatorial Pacific region. It is more likely that this period is recognized in a various depositional environments, suggesting that this period is not affected by the environment (Fig. 5).

Piston core samples were taken and heat flow measurements were made in the Iheya-north hydrothermal site in the mid-Okinawa Trough. High heat flow area is widely distributed, but is surrounded by very low heat flow, suggesting a recharge of sea water into the formation.

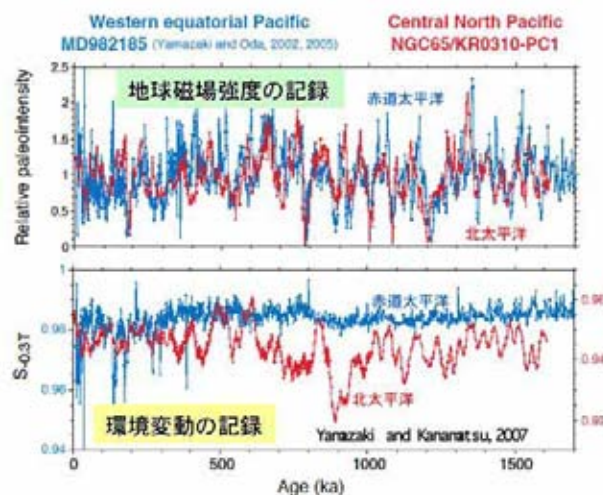


Fig. 5 Comparison of geomagnetic intensity in the equatorial and northern Pacific sites. (Top) Record of geomagnetic field intensity in the Equatorial (blue) and Northern (red) Pacific. (Bottom) Record of environmental variation.

(2) Research Program for Geochemical Evolution

The Research Program for Geochemical Evolution aims to comprehensively understand the evolution of the solid Earth based on petrological and geochemical approaches for subduction zones and hotspot magmas, and experimental studies for Earth materials at high pressures and temperatures.

a. Evolution of the Izu-Bonin-Mariana (IBM) intra-oceanic arc crust and its bearing on continental crust formation

Continental crust possesses an average composition equivalent to intermediate igneous rocks, such as andesites that typify arc magmatism, and hence is believed to have been created in subduction. A seismic expedition in the Izu-Bonin-Mariana (IBM) arc has documented the occurrence of middle crust with a P-wave velocity (V_p) of ~ 6 km/s, providing a compelling reason for believing that intermediate crust, and more speculatively continental crust, is created in an oceanic arc. There remains, however, a significant dilemma that we are faced with and need to overcome to better understand the process of intermediate continental crust formation; that is, although mantle-derived andesitic arc magmas have been produced under unusual tectonic settings, magmas generated in the mantle wedge in general possess basaltic compositions. If so, then the process and mechanism of differentiation from initial mafic crust to intermediate continental crust need to be understood.

Characteristic seismic structural features of the IBM arc (Fig. 1) highlighted in this modeling include the presence of (1) a middle crust with a P-wave velocity (V_p) of 6.0-6.5 km/s, (2) a 6.5-6.8 km/s V_p layer at the top of the lower crust, (3) a high-velocity ($V_p=6.8-7.2$ km/s) lower crust, and (4) an uppermost mantle exhibiting rather low velocities ($V_p=7.4-7.7$ km/s). The petrologic modeling includes: 1) estimation of lithology of the crust and mantle layers based on constraints from crustal rocks collected so far, 2) quantitative analyses of magmatic differentiation based on experimental constraints, and 3) estimation of the crustal and mantle profile of physical properties.

In the theoretical approaches to seismic velocity estimates, the properties of individual minerals are first corrected for the effects of pressure and temperature and then used to calculate the properties of the aggregate mineral assemblage using the

average of Hashin-Strikman bounds. In our calculation, the density, V_p , and V_s of the layers, composed of the inferred mineral assemblages, are calculated along geotherms (Fig. 1). The V_p calculated for the inferred compositions for each layer of the IBM crust on the basis of the basalt model is consistent with the observed values, whereas the andesite model cannot account for the characteristic V_p of the middle crust, the uppermost lower crust and the uppermost mantle. The density inversion is predicted within the uppermost mantle in the basalt model, suggesting the role of delamination of dense materials in this layer in the structural and chemical evolution of the arc system.

The modeling results further suggest that the volume of mafic restite and cumulates that are 'crustal residues' resulting from the evolution of middle and upper arc crust is, at least, three to nine times greater than that of the seismically defined IBM lower crust (Fig. 2.). One possible explanation to overcome this apparent dilemma is that the mafic to ultramafic crustal components are transformed to subarc mantle to form the uppermost mantle layer. If so, then the sub-arc Moho is chemically transparent and permeable to the crustal components during the arc crust evolution. This crust-mantle transformation could play the major role in the creation of mature arc crust with intermediate compositions similar to continental crust. As a result, we suggest that the Moho beneath the active arc is not a fixed material boundary, but transparent and permeable to mass transfer across it.

Figure 3 schematically shows a hypothesis on the arc crust

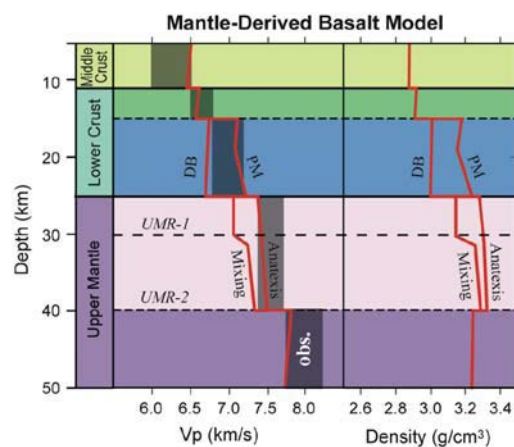


Fig. 1 V_p and density calculated for the inferred lithologies in sub-IBM crust and mantle (red lines) along an inferred geotherm. The inferred model of arc crust evolution, especially the anatexis model, provides V_p consistent with the observed V_p (dark regions; obs.). DB, differentiated basalt; PM, primary basalt.

evolution and the nature of the sub-arc Moho. At the pre-arc stage, the Moho separates the oceanic crust and mantle. Arc magmatism creates an initial arc crust with a basaltic composition. At the juvenile arc stage, successive basaltic underplating causes anatexis of the initial basaltic crust to form a partially molten zone composed of mixture of melts and restites. A rather sharp boundary between regions within the arc crust where melt is present and absent (melting front), which may be termed the 'pseud-Moho', grows up to be the sub-arc Moho, which is defined the boundary between the remaining basaltic arc crust and the restite layers. Intermediate to felsic partial melts segregate from the restite and migrate upward across the pseudo-Moho to form the middle crust. During this differentiation process, crustal residues composed of restites and cumulates are transformed to the mantle, developing a subarc uppermost mantle with a relatively low- V_p . The crust-mantle transformation of mafic components results in formation of differentiated or less mafic arc crust; the modeling results indicate that the present total IBM arc crust may have 52-54 wt % SiO_2 , whereas the original arc crust is assumed to be basaltic (50 wt % SiO_2). Further differentiation of the crust through both anatexis of the initial basaltic crust and transformation of mafic crustal components into the mantle changes the total arc crust composition to create a mature arc crust with an intermediate composition. It may be thus suggested that melt migration across the chemically transparent Moho and the crust-mantle

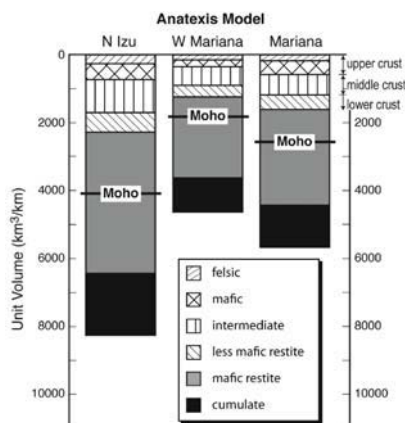


Fig. 2 Unit volume of each layer of the IBM crust across three cross-arc sections; Northern Izu, Western Mariana and Mariana. Volumes of the mafic restite and cumulate layers are calculated based on the observed volume of upper and middle crust and the low-velocity (less mafic) layer at the top of the lower crust. The seismically determined Moho is located within the mafic restite/cumulate layer, thus the 'crustal excess' is distributed in the upper mantle beneath the Moho in the IBM system.

transformation of mafic components play the key role in the formation of continental crust in intra-oceanic arcs.

b. Genesis of deep-mantle geochemical reservoirs: HIMU

It is widely accepted that the mantle is heterogeneous and consists of several distinct components (end-members) such as DM, PM, HIMU, EM1 and EM2. In order to constrain the origin of end-members, the time of differentiation and the scale of heterogeneity in the mantle, we conduct geochemical studies to re-characterize the mantle end-members by integrating geochemical tools including more than ten isotopic systems with high-precision and reliable analyses. Progress of the on-going project for Polynesian HIMU is presented here.

HIMU has been considered to be a subducted ancient oceanic crust that was dehydrated during subduction. This hypothesis is tested by our new data and the following con-

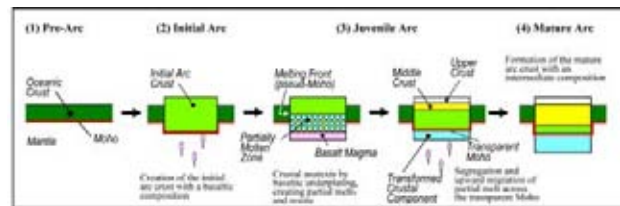


Fig. 3 A model of arc crust evolution. Incipient arc magmatism replaces the pre-existing oceanic crust to create the initial basaltic arc crust. Successive arc magmatism causes anatexis and differentiation of the arc crust, along with upward migration of intermediate melts across the pseud-Moho and transformation of mafic crustal component into the mantle. This finally creates the mature arc crust with an intermediate composition similar to the average continental crust.

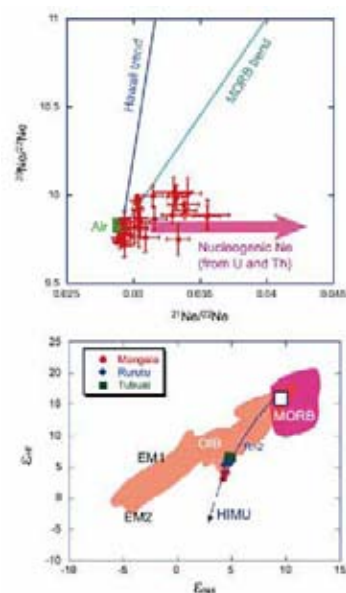


Fig. 4 Ne isotope data (top) and Nd and Hf isotope data (bottom) from the Polynesian HIMU basalts.

straints have been obtained. (1) Isotopic data using mineral samples are free from the secondary effects, such as crustal contamination and weathering. Mineral analyses thus enable us to resolve clear mixing relationships between components. (2) HIMU basalts are enriched in radiogenic ^4He and nucleogenic ^{21}Ne that are the decay products of U and Th, compared to the depleted mantle and less-degassed mantle (Fig. 4, top). This suggests that the source of HIMU was ancient subducted slab that had been depleted in noble gases and enriched in U and Th. (3) Very low Rb/Sr and Pb/Hf ratios as deduced from Pb-Sr-Nd-Hf isotopic systematic demonstrates that the HIMU source was depleted in fluid-mobile elements. This is consistent with the model that origin of HIMU was a dehydrated slab. (4) In contrast to fluid-mobile elements and their isotopes that had been affected by subduction processes, fluid-immobile elements and their isotopes, such as Sm-Nd and Lu-Hf isotope systems, should provide the information of the source before subduction. Nd and Hf isotope ratios and Nd/Hf ratios of HIMU (Fig. 4, bottom), however, cannot be simply explained by the above-mentioned hypothesis of recycling of oceanic crust that had the similar composition to the present oceanic crust. A possible interpretation is that the ancient oceanic crust, that was the source of HIMU, was produced from more fertile mantle than present. (5) Any core-signature in W isotopes were not detected for Polynesian HIMU samples, thereby it is still enigmatic whether the ancient oceanic crust was subducted to reach the

bottom of the mantle.

c. Properties of the Earth's interior: towards to center of the Earth

Sinking of mid-oceanic ridge basalt (MORB) causes strong chemical heterogeneities in Earth's mantle, possibly extending down to the core-mantle boundary. Phase relations in both pyrolitic mantle and MORB compositions are precisely determined at high pressures and temperatures corresponding to lowermost mantle conditions. The results demonstrate that the post-perovskite phase transition occurs in pyrolite between 116 and 121 GPa at 2500 K, while post-perovskite and SiO_2 phase transitions occur in MORB at ~ 4 GPa lower pressure at the same temperature. Theory predicts that these phase changes in pyrolite respectively. Near the northern margin of the large low shear velocity province in the lowermost mantle beneath the Pacific, reflections from a negative shear velocity jump near 2520-km depth are followed by reflections from a positive velocity jump 135 to 155-km deeper. These negative and positive velocity changes are consistent with the expected phase transitions in a dense pile containing a mixture of MORB and pyrolitic material (Fig. 5). This may be a direct demonstration of the presence of accumulations of subducted MORB crust in the deep mantle.

Geomagnetic observations have shown that the electrical conductivity of the upper to middle part of the lower mantle is 1 to 10 S/m, consistent with the laboratory measurements of the conductivity of silicate perovskite. A possible existence of a highly conductive layer has been often suggested in the deepest mantle from geophysical modeling. Recent discovery of a phase transition from perovskite to post-perovskite suggests that the physical properties of the Earth's lowermost mantle, called the D" layer, may be different from those of the overlying mantle. We report that the electrical conductivity of $(\text{Mg}_{0.9}\text{Fe}_{0.1})\text{SiO}_3$ post-perovskite is $>10^2$ siemens per meter and does not vary greatly with temperature at the conditions of D" layer (Fig. 6). A post-perovskite layer above the core-mantle boundary would, by electromagnetic coupling, enhance the exchange of angular momentum between the fluid core and solid mantle, which can explain the observed changes in length of a day on decadal

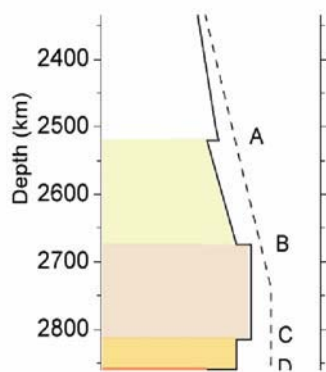


Fig. 5 The velocity profiles for PREM and SPAC3. SPAC3 had four velocity discontinuities (A, B, C, D) that produce reflectivity associated with the corresponding labeled peaks on the left. For the interpretation of this region as a MORB-pyrolite mixed pile, discontinuity A results from post-perovskite and SiO_2 phase transitions in the MORB component, discontinuity B from post-perovskite phase transition in the pyrolitic component, discontinuity C from back transformation of the post-perovskite to perovskite in the pyrolitic material due to rapid temperature increase, and discontinuity D from onset of partial melting just above the CMB.

timescales. Heterogeneity in the conductivity of the lowermost mantle is likely to depend on changes in chemistry or mineralogy of the boundary region, not fluctuations in temperature. Properties of FeS under high pressure have been of great interest in Earth and planetary sciences, as considerable amount of sulfur is possibly incorporated in iron-rich Earth's core. In order to better assess this problem, we have established techniques for XRD measurements of FeS up to 270 GPa. FeS exhibits extensive polymorphism at high pressure and temperature, all with NiAs-type (B8) or closely related structures. Here we report a new phase transition from FeS VI to CsCl-type (B2) phase (FeS VII) above 180 GPa based on the synchrotron x-ray diffraction (XRD) measurements. A significant volume reduction by 3.0% was observed at the phase transition (Fig. 7), due to an increase in the coordination number from six to eight. Present results suggest that substantial amount of sulfur may be incorporated into an Fe-Ni alloy with bcc structure in the Earth's inner core.

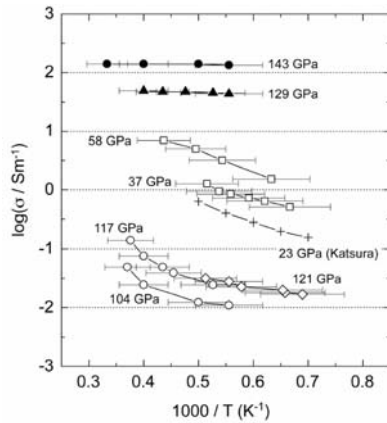


Fig. 6 Electrical conductivity (σ) of perovskite and post-perovskite as a function of reciprocal temperature. Squares, run #1; circles, run #2; triangles, run #3; diamonds, run #4. Open and closed symbols indicate measurements of perovskite and post-perovskite, respectively. Previous data on perovskite by Katsura et al. are also presented by crosses. The measured variations in temperature between the electrodes are shown by error bars.

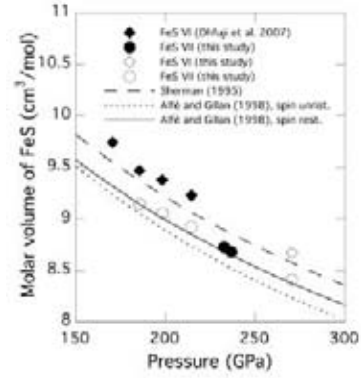


Fig. 7. Experimentally observed molar volumes of FeS VI and VII, and pressure-volume relations based on the first-principles calculations (Sherman 1995; Alfè and Gillan 1998). Closed diamonds, Ohfuji et al. (2007); open diamond, this study, $a=4.4070(15)$ Å, $b=2.8179(11)$ Å, and $c=4.6453(8)$ Å; closed circle, FeS VII calculated from four peaks; open diamond, FeS VI, not annealed, $a=4.4070(15)$ Å, $b=2.8179(11)$ Å, and $c=4.6453(8)$ Å; open circle, FeS VII estimated only from 110 peak. The absolute volumes of FeS VII are the most consistent with the results of Alfè and Gillan (1998) with spin restricted calculations.

(3) Research Program for Plate Dynamics

1) Lithospheric structure research

a. A high-resolution 3D seismic reflection survey and prestack depth imaging in the Nankai Trough off southeast Kii Peninsula

The IODP NanTroSEIZE project will commence drilling into the seismogenic portion of the megathrust along which the 1944 Tonankai earthquake ($M = 8.1$) has occurred off the Kii Peninsula, southwest Japan. In order to figure out high-resolution structure and physical property of the subducting Philippine Sea Plate (PSP) consisting of oceanic crust and incoming sedimentary strata, we have performed a high-resolution, three dimensional (3D) multi-channel seismic (MCS) reflection survey (KR06-02 cruise) in the Nankai Trough off Kii Peninsula using R/V Kairei of the Japan Agency for Marine-Earth Science and Technology in March 2006. This Kairei 3D survey area covers three drilling sites of the NanTroSEIZE. For the high-resolution 3D MCS survey, we used a ~5-km, 204-channel streamer and ~100 m separated dual source, each of which is composed of two G-guns plus a GI-gun. Flip-flop shooting with 30 m interval yields ~50 m separated two CMP lines, resulting in 3.5 x 52 km 3D seismic volume. We have constructed and updated interval velocity volume model for 3D prestack depth migration (PSDM) following 3D prestack time migration (Fig. 1) using those CMP bin gathers. Final 3D PSDM result shows high-resolution seismic

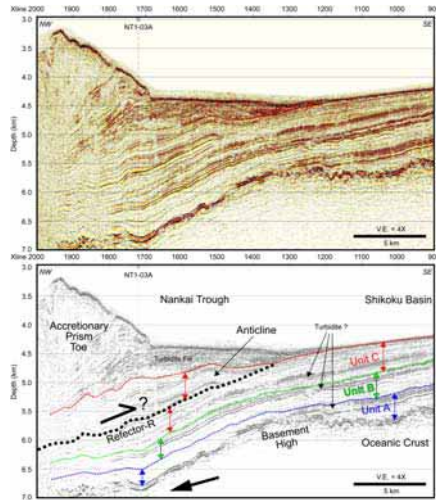


Fig.1 Blown-up seismic reflection profile (upper) and interpretation (lower) between crossline 900 and 2000 along inline 95 shown in Fig. 6. One of the NanTroSEIZE drilling sites, NT1-03A, is shown.

images of three Miocene to Pliocene Shikoku Basin sedimentary units (Units A, B, and C) including three remarkable turbidites. The oceanic crust of the subducting Philippine Sea Plate underthrusts the overlying the accretionary prism, and is traceable over the entire inlines. In particular, Unit C beneath the trough turbidite fill shows unusual increase of thickness and anticline structure, which have never been reported in the Nankai Trough. We observe a noticeable, strong reflector (Reflector-R) immediately beneath the anticline structure, which is located at almost mid-level of the Unit C. We interpret that both the anticline structure and thickness increase might be resulted from duplication of stratigraphic section following oblique slip up the sidewall ramp.

b. Fault configuration produced by initial arc rifting in the Parece Vela Basin as deduced from seismic reflection data

The Parece Vela Basin (PVB), which is a currently inactive back arc basin of the Philippine Sea plate, was formed by separation between the Izu-Ogasawara arc (IOA) and the Kyushu-Palau Ridge (KPR). Elucidating the marks of the past back-arc opening and rifting is important for investigation of its crustal structure. To image its fault configurations and crustal deformation, we applied prestack depth migration to multi-channel seismic reflection data obtained by the Japan Agency for Marine-Earth Science and Technology and Metal Mining Agency of Japan and Japan National Oil Corp. (Japan Oil, Gas

and Metals National Corp.) (Fig. 2). Salient results for the prestack depth-migrated sections are: (1) deep reflectors exist around the eastern margin of KPR and at the western margin of IOA down to 8 km depth. (2) normal fault zones distributed at the eastern margin of the KPR (Fault zone A) and the western margin of the IOA (Fault zone B) have a total displacement of greater than 500 m associated with synrift sediments. Additional normal faults (Fault zone C) exist 20 km east of the Fault zone B. They are covered with sediment, which indicates deposition of recent volcanic products in the IOA. According to those results, (1) the fault displacement of more than 500 m with respect to initial rifting was approximately asymmetric at 25 Ma based on PSDM profiles; also (2), the faults had reactivated after 23 Ma, based on the age of deformed sediments obtained from past ocean drillings. The age of the base sediments corresponds to those of spreading and rotation after rifting in the PVB. Fault zone C is covered with thick and not deformed volcanogenic sediments from the IOA, which suggests that the fault is inactive.

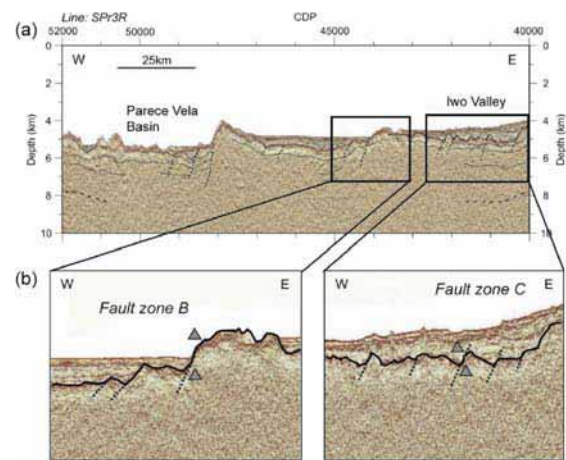


Fig. 2 Prestack depth migrated section and final velocity model of line SP3R.

c. New seismological constraints on growth of continental crust in the Izu-Bonin intra-oceanic arc

The process by which continental crust has formed is not well understood, though such crust mostly forms at convergent plate margins today. It is thus imperative to study modern intra-oceanic arcs, such as are common in the Western Pacific Ocean. New seismic studies along the representative Izu-Bonin intra-oceanic arc provide unique along-strike images of arc crust and

uppermost mantle to complement earlier, cross-arc lithospheric profiles (Fig. 3). These reveal two scales (1000-10 km scale) variations, one at the scale of the Izu vs. Bonin (thick vs. thin) arc crust the other at the inter-volcano (~50 km) scale. These images show: 1) bulk composition of the Izu - Bonin arc crust is more mafic than typical continental crust; 2) middle crust with seismic velocities similar to continental crust lies predominantly beneath basaltic arc volcanoes; 3) bulk composition beneath basaltic volcanoes changes little at thick and thin arc segments; and 4) a process to return lower crustal components to the mantle, such as delamination, is required for an arc crust to evolve into continental crust. Continued thickening of the Izu - Bonin crust, accompanied by delamination of lowermost crust, can yield velocity structure of typical continental crust.

d. Structure and growth of the Izu-Bonin-Mariana arc crust - seismic constraint on crust and mantle structure of the Mariana arc - backarc system -

A high-resolution seismic velocity model is presented for the crust and upper mantle of the Mariana arc-backarc system (MABS) based on active-source seismic profiling (Fig. 4). The major characteristics are (1) slow mantle velocity of < 8 km/s

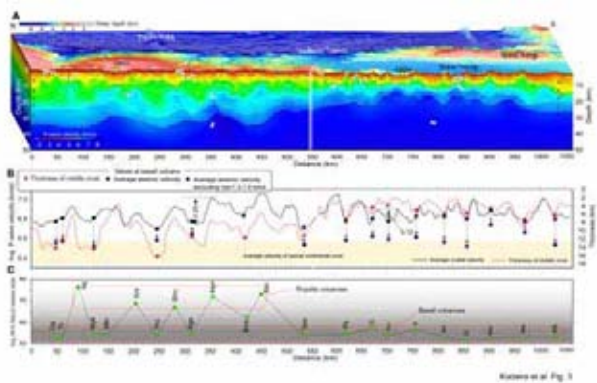


Fig. 3 (Top) Seismic velocity image along the volcanic front from the Izu to the Bonin arc obtained by seismic refraction tomography. Layers A - E indicate geological interpretations of the seismic image. A, upper crust consisting of sediment, volcanoclastics and volcanic rocks; B, felsic composition plutons; C, intermediate composition plutons; D, mafic plutons; E, mafic to ultra-mafic cumulates; F upper mantle. (Middle) Average crustal seismic velocity (black line) and thickness of the middle crust ($V_p = 6.0-6.8$ km/s) (red line), which is interpreted to be plutonic rocks of felsic to intermediate composition. Black and red dots indicate average seismic velocities and thicknesses of the middle crust, respectively, beneath basaltic volcanoes. Blue dots show average crustal seismic velocities beneath basaltic volcanoes, but excluding the $V_p = 7.2-7.6$ km/s component. Orange shading shows the velocity range of typical continental crust. (Bottom) Average wt % SiO_2 of volcanic rocks sampled and dredged from Quaternary volcanoes.

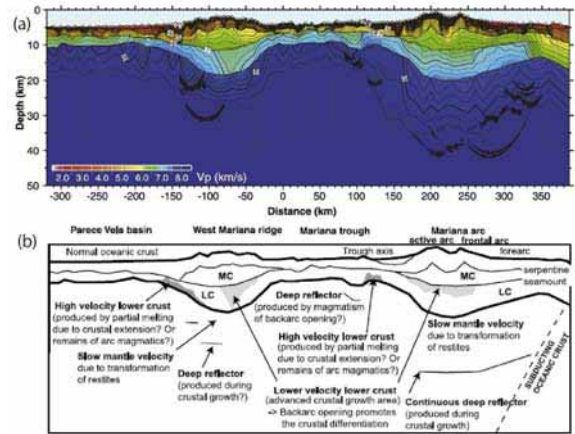


Fig. 4 Final velocity models of the Mariana arc-backarc system and the interpretations. (a) Velocity model. Solid circles indicate locations of OBSs. An interval of velocity contour is 0.1 km/s. Shaded area indicates the poorly resolved region identified by ray density map. (b) Interpretations.

in the uppermost mantle, especially , and deep reflectors under the Mariana Arc (MA) and the West Mariana Ridge (WMR), (2) a deep reflector in the upper mantle beneath the relative thick crust of the Mariana Trough (MT) axis, (3) distribution of lower-velocity lower crusts (6.7-6.9 km/s) beneath the volcanic front and adjacent to the MT, and (4) high-velocity lower crust (7.2-7.4 km/s) beneath the boundary regions between the MA and MT, and between the WMR and the Parece Vela Basin (PVB), adding to structural characteristics of crust and upper mantle beneath the MABS. Of the characteristics described above, (1) suggests that the origins of the slow mantle velocity and the deep reflectors be explained by transfer of the lower crustal residues to the upper mantle across the Moho, considering that the WMR is extinct arc currently. On the other hand, (2) suggests that the origin of deep reflectors beneath the MT axis might be lower velocity materials due to the diffractive signals with strong amplitudes, (3) suggests that the lower-velocity lower crust advanced crustal growth and (4) suggests that the high-velocity lower crust beneath arc-backarc transition zone is composed of mafic/ultramafic materials created by extensive partial melting of mantle peridotites or last stage of the arc magmatism rather than serpentinized peridotite.

e. Interactive analysis tools for the wide-angle seismic data for crustal structure study

The wide-angle seismic reflection/refraction data analysis play important roles in the lithospheric scale crustal structure

study. However, it is extremely difficult to develop an appropriate velocity structure model directly from the observed data and we have to improve the structure model step by step, because the crustal structure analysis is an intrinsically nonlinear problem. There are several subjective processes in the wide-angle crustal structure modeling, such as phase identification and the trial-and-error forward modeling. Because these subjective processes in the wide-angle data analysis reduce the uniqueness and credibility of the resultant models, it is important to reduce subjectivity from the analysis procedure. From this point of view, we develop two software tools, PASTEUP and MODELING, for developing crustal structure models. PASTEUP is an interactive application facilitates for plotting record sections, analysing wide-angle seismic data and picking phases. PASTEUP is equipped with various filters and analysis functions to enhance signal-to-noise ratio and to help phase identification. MODELING is an interactive application for editing velocity model and ray-tracing. Synthetic traveltimes computed by the MODELING can be directly compared with the observed waveforms in the PASTEUP. This reduces subjectivity from the crustal structure modeling because traveltimes picking, which is one of the most subjective process in the crustal structure analysis, is not required. MODELING can convert an editing layered structure model into two-way traveltimes and can be compared with the time-section of the Multi Channel Seismic (MCS) reflection data. The direct comparison between the structure model of wide-angle data with the reflection data will give the model more credibility. In addition, both PASTEUP and MODELING are efficient tools for handling a large data set. These software tools help us develop more plausible lithospheric scale structure models using wide-angle seismic data.

f. Thermal pressurization and slip-weakening distance of subduction thrusts

We identify a geological evidence of thermal pressurization from the on-land analogue of a subduction thrust exhumed from seismogenic depths, which is represented by fluidization of the granular material and increase in volume of fluid inclusions by increased heating. Numerical analysis of thermal pressurization using natural data of slip zone thickness, tempera-

tures during frictional heating, and ambient conditions of subduction thrusts indicate that a slip-weakening distance (D_c) of subduction thrusts ranges from 0.03 to 0.22 m (Fig. 1). Our results indicate that thermal pressurization can induce dynamic weakness and unstable fault motion of subduction thrusts during subduction earthquakes.

g. Mechanisms for variation in size and occurrence interval of interplate earthquakes

There are some systematic variations in size and recurrence interval of earthquakes in subduction zones. Such varia-

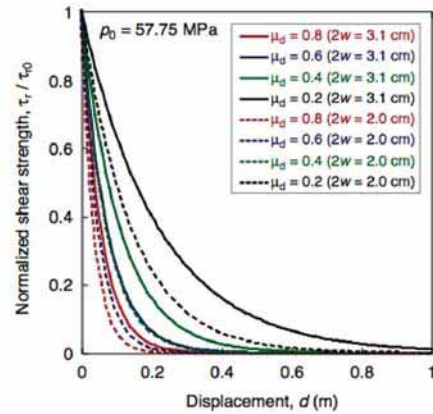


Fig. 5 Slip-weakening curves associated with thermal pressurization with an initial hydrostatic pore fluid pressure ($p_0 = 57.75$ MPa) as shown by normalized shear strength (τ_r / τ_0) against fault displacement (d). Solid and dashed lines indicate slip-weakening curves when the thickness of the slip zone ($2w$) is 3.1 cm and 2.0 cm, respectively.

tions, especially variation in recurrence time depending on earthquake size, are incorporated in hazard predictions for earthquakes in many countries including Japan, although the physical mechanism has not been revealed yet. We model an interplate earthquake as release of slip deficit with high slip rate. The slip deficit accumulation occurs on an area where slip velocity is significantly lower than the surrounding area mainly due to mechanical coupling of plate boundary. Spatial and temporal variation in slip on a plate boundary can be described mathematically with equations for stress change due to slip, a relation between stress, strength and slip velocity, and an evolution law of strength. Numerical simulations based on such model with heterogeneous frictional property qualitatively reproduce the variation pattern of size and time interval of great interplate earthquakes in some subduction zones. The recurrence time variation depending on size for the Nankai subduc-

tion zone arises from the specific layout of inhomogeneities of the region. Since such variations are seen in other subduction zones, there may exist other mechanisms related to specific or general patterns of heterogeneity in frictional properties.

h. NUMERICAL ANALYSIS OF GROWING CRACK PROBLEMS USING ARTICLE DISCRETIZATION SCHEME

This study presents the particle discretization scheme to analyze brittle failure of solids. The scheme uses characteristic functions of Voronoi and Delaunay tessellations to discretize function and its derivatives, respectively. A discretized function has numerous discontinuities so that these discontinuities are utilized as a candidate of crack path segment in modeling propagating cracks, without making any extra computation to accommodate new displacement discontinuities. When the scheme is implemented to a finite element method, the resulting stiffness matrix coincides with the one that is obtained by using linear elements. The accuracy of computing a stress intensity

factor at a crack tip is examined. It is shown that the accuracy is better than that of a finite element method with linear elements when rotational degree-of-freedom is included in discretizing displacement functions. Three three-dimensional growing crack problems are solved by means of the particle discretization scheme, and example result is presented (Fig.3).

i. Symbolic Dynamics in Metamorphic Rocks 3 - Instability of Metasomatic Banding Interface and Fluid Flux

Banding and domain structure of minerals in the plate boundary metamorphic rocks are very common and they are potentially investigated by means of nonlinear symbolic dynamics (Toriumi, 2007). The symbolic dynamics indicates the invariant set of periodicity arising in the simple nonlinear dynamical phenomena. The basics of symbolic dynamics for banding and domains of minerals is the metamorphic process governed by reaction and diffusion of ionic species in the plate boundary fluid phase. This type of reaction and diffusion

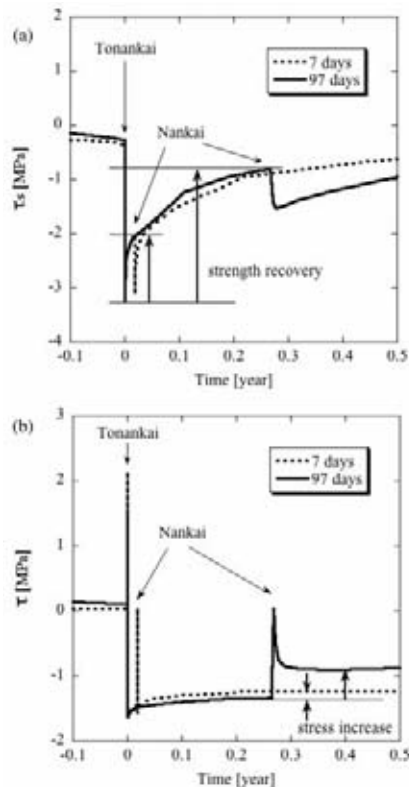


Fig.6 (a) Temporal variation in strength near the hypocenter of simulated Tonankai events for two cases. The time interval of Tonankai and Nankai events are 97 days and 7 days for solid and broken lines, respectively. The origin of horizontal axis is the occurrence time of each Tonankai event. The timing of Nankai events and strength recovery indicate by arrows. (b) Temporal variation in stress at the same point as (a). The timing of Nankai events and stress increase due to Nankai events indicate by arrows. The difference in stress increase causes the variation in recurrence interval of Tonankai events.

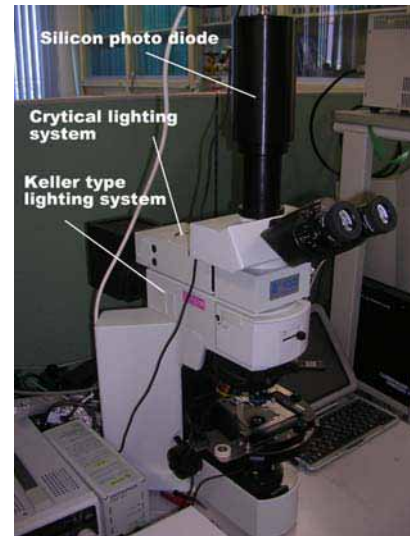


Fig.7 Torsional failure simulated by proposed method.

dynamics is characterized by strong nonlinear style because rates of mineral growth and dissolution from very small amount of metamorphic solution depend upon powers of ionic concentrations. If this is the case, wavy interfaces between bands and domains resulting from boundary instability should be common in metamorphic rocks.

The authors investigated the interface instability of the metasomatic banding produced by diffusion zones between basic and carbonates metamorphic rocks. The interfaces between wollastonite and garnet bands and between garnet and clinopyroxene bands display commonly waveform and the dominant wavelengths of interfaces seem to be similar in their Fourier spectra (Toriumi and Fukuyama, 2008). It suggests strongly that the stationary diffusion of component ions in porous fluid operates with frontal dissolution and growth of minerals at the bands interfaces. Further, it is very important that interface waveforms show the phase lock and antilock between two advancing interfaces. The interface dynamics satisfying this type of correlated motion involves fluid flux and ionic diffusion across the interface.

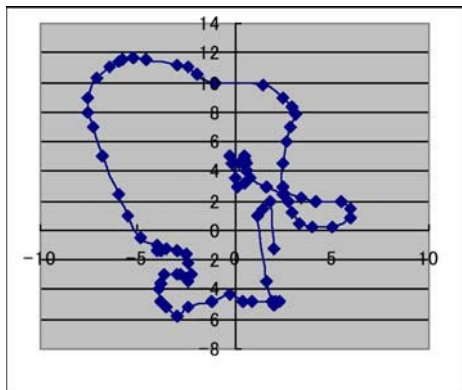


Fig.8 Correlation map of studied band interfaces I(horizontal) and II(vertical) in single metasomatic banding structure.

(4) Research program for Paleoenvironment

Surface environments vs. activity of Earth's interior

a. Earth's internal activities recorded in the sediment

Earth's history has been punctuated over at least the last 3.5 billion years by massive volcanism. It generated large volumes of predominately mafic magmas being emplaced onto the Earth's surface by processes and mechanisms largely unknown, and unrelated to seafloor spreading or subduction. These formed large igneous provinces (LIPs) that were usually accompanied by catastrophic environmental change. Environmental effects associated with LIP formation include global warming, biological mass extinctions, variations in ocean and atmospheric chemistry, including Oceanic Anoxic Events (OAEs) which is characterized by deposition of organic-rich black shales. Therefore, the mantle geodynamic processes that produce LIPs have potentially profound effects on the Earth's biosphere and climate. The massive volcanisms are recorded in the oceanic sediments and sedimentary rock. In FY2007, one of the successful such efforts is related to the Earth's surface environment around OAE-1a and OAE-2 that respectively occurred around 94 and 124 Ma, when the volcanic activities were also enhanced.

The mechanism connecting between LIP emplacement and OAE formation in Cretaceous have been investigated with multi-disciplinary collaboration with members from IFREE-4 and IFREE-5. Of these, a project measuring of carbon, lead, and osmium isotopic compositions of a sedimentary sequence around OAE-1a (Selli Event) provided strong evidence that the LIP formation ultimately triggered OAE (Tejada et al., revised; Kuroda et al., in prep.). Based on age determinations of basaltic rock, it has long been known that the timing of formation of Ontong Java Plateau (OJP), the largest LIP ever formed, is 126-119 Ma, which is close to the timing of OAE-1a (~124 Ma). Therefore, it has been discussed whether or not both events are mechanically connected.

In FY 2007, we first determined osmium isotopic composition ($^{187}\text{Os}/^{188}\text{Os}$ ratio) for the sedimentary sequence including OAE-1a black shale deposited in the western Tethys with temporally high resolution. At the lowest level of OAE-1a black shale, we observed a sharp, large negative shift of Os isotopic

compositions down to 0.16 (Fig. 1), throughout the OAE-1a sequence, suggesting that the isotopic composition of Os dissolved in seawater substantially decreased during that time. Marine Os isotopic record is a function of changes in the balance among three major sources of input to the ocean and an output to the sediment. The mantle and cosmogenic inputs are unradiogenic with Os isotopic composition 0.12-0.13. It implies that the extensive volcanism (probably associated with the OJP formation) simultaneously occurred with the formation of OAE-1a. Based on the simple one-box model calculation, more than 2×10^6 t Os had to be released from the mantle to the ocean.

may be an important process to bridge these events. A one-dimensional ocean modeling is being constructed and evaluated above process (Misumi, 2007).

In FY2007, we extensively applied the method to the Cretaceous black shales to understand the surface ocean ecology and environment during the OAEs. The nitrogen isotopic compositions of most alkyl porphyrins from black shales in OAE-1a and OAE-2 range from -8 to -2 per mil (Fig. 3). The isotopic results strongly suggested that the diazotrophic (i.e., N₂-fixing) cyanobacteria were major drivers to fertilize euphotic zone of surface ocean during the OAEs (Ohkouchi et al.,

Fig 1 Carbon (blue) and osmium (red) isotopic compositions in the sedimentary sequence from central Italy (Tejada et al., revised). OAE-1a (Selli event, blue zone) around 124 Ma is temporally correlated with a negative isotopic excursion of Os which may be related with the eruption of Ontong Java Plateau, a Pacific large igneous provinces. Estimated Os flux from mantle based on a one-box model is shown on the right diagram.

Fig. 2 Chemical structure of chlorophyll a and porphyrin diagenetically derived from nucleus of chlorophyll a. Photos of isolated chlorophyll a from modern higher plants (left, lower) and porphyrin (Deoxoerythroetioporphyrin) from Cretaceous black shale (right, lower) are also shown.

2007; Ohkouchi et al., 2008; Kashiyama et al., 2008). Furthermore, we observed abundant highly branched isoprenoids (HBI) derived from Rhizosolenid diatoms in these black shales. These observations with other various geological evidence lead us to hypothesize that the symbiosis between diazotrophic cyanobacteria (*Richelia* sp. or *Hemiaulus* sp.) with Rhizosolenid diatom may have played an important role in the biological productivity in stratified oligotrophic ocean during the OAEs.

Furthermore, in collaboration with CDEX in JAMSTEC, we are currently planning a D/V Chikyu cruise to evaluate the drilling technologies for recovering chert/shale (hard/soft) sequences. Despite of many drilling efforts by DSDP/ODP during the last 30 years, they largely lack Cretaceous strata, especially for OAE black shales because of very low recovery due to the laminated chert sequences. Therefore, a novel drilling technology is essential for investigating Cretaceous OAEs in the pelagic Pacific basin where have largely unexplored yet. We plan to overcome the low-recovery problem by using state-of-the-art drilling technology of D/V Chikyu. The influence of oceanic environments related to the formation of Ontong Java Plateau, the largest LIP ever found and formed simultaneously with the OAE-1 and the onset of Cretaceous superchron will be a primary focus of this drilling.

b. Deep biosphere studies: Results from D/V Chikyu shake-down cruise

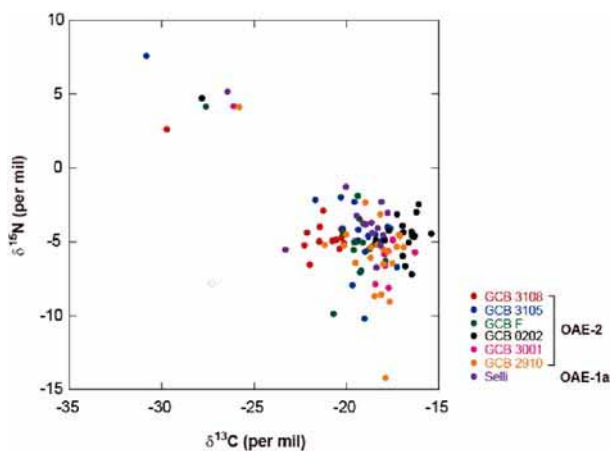


Fig. 3 Carbon and nitrogen isotopic compositions of various species of alkyl porphyrins isolated from OAE black shale samples (OAE-1a and OAE-2) collected from central Italy. The nitrogen isotopic compositions of most porphyrins range -5 ± 3 per mil, suggesting them to be derived from N_2 -fixation process.

During the shakedown cruise of D/V Chikyu (CK05-04 and CK06-06), they collected several sediment cores from off Shimokita Peninsula. Using these samples, in IFREE4, efforts have been made 1) to obtain ancient DNA from the sediments, and 2) to determine the microbial processes with both carbon and nitrogen isotope analyses of single species of bacteria isolated from the sediments in collaboration with Kochi Institute for Core Sample Research (Inagaki et al., submitted).

The purpose of the former study is to establish a method for extracting ancient DNA from eukaryotic unicellular microorganisms (so-called protists), including planktonic microalgae, from the sediment. Fossil DNA has the potential to clarify the relationship between changes in water-mass properties and differentiation of a genetic population in the geological past. We extracted DNA from 59 layers, two from core C9001A, 13 from cores C9002A and B, and 44 from core C9001C. We also compared methods of extracting DNA from the sediments. PCR amplification and clone analyses of these DNA extracts were carried out with both universal eukaryotic primer pairs and specific primer pairs for diatoms and haptophytes. Our molecular analyses showed that we retrieved DNA of eukaryotic planktonic microalgae (mainly diatoms) from the sediment surface down to 45 m (Fig. 4). The lowest layer from which we retrieved diatom DNA corresponded to ca. 50 ka. In the surface sediment, we identified DNA of various protists,

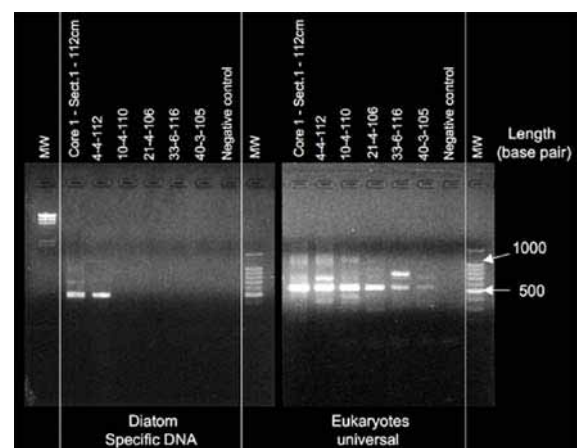


Fig. 4 An example of amplified DNA fragments by using both specific and universal primer pairs. Our sequence analyses showed that we retrieved DNA of eukaryotic planktonic microalgae (mainly diatoms) from the sediment surface down to 45 m (core 5, section 4). The lowest layer from which we retrieved diatom DNA corresponded to ~50 ka (left). In the surface sediment (core 1), we identified DNA of various protists, whereas DNA clones were mainly from diatoms below core 2~core 5 (right).

whereas DNA clones were mainly from diatoms below core 2. The obtained nucleotide sequences were similar to the partial diatom sequence of 18S ribosomal RNA gene of *Chaetoceros socialis* (AY485446) (97% similarity). At least four *Chaetoceros* genotypes were found in C9001C core. It is possible that each layer contains several different populations and populational changes occurred through the time.

Furthermore, intact polar lipids (IPLs) are currently investigated in detail using nuclear magnetic resonance (NMR) and high-performance liquid chromatography/mass spectrometry to understand the biogeochemical processes mediated by archaea inhabiting in the sediments. Both genetic and biomarker information will provide crucial information on the deep biosphere.

(5) Program for Data and Sample Analysis

1) Geophysical observation network

IFREE has been operating the geophysical observation network in Northwestern Pacific region. Figure 5.1 shows station distribution of broadband seismographic station. This year, we have successfully finished an installation of broadband seismograph and data logger at Kepahyan in Sumatra Island (KSI) in collaboration with the National Institute for Earth Science and Disaster Prevention (NIED) and Indonesia Meteorological Agency. Immediately after the installation of the seismograph, a strong earthquake occurred on September 12, 2007 just off shore of the KSI station. The magnitude of this earthquake was $M_w=8.6$ and the epicentral distance to the station was less than

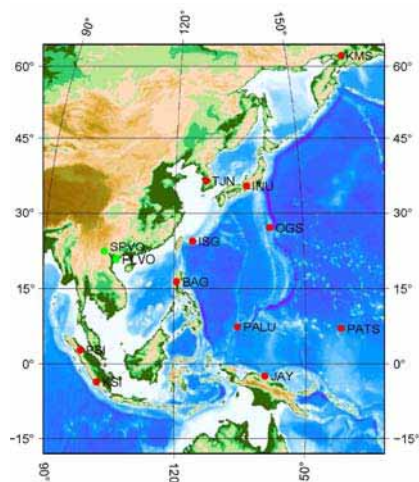


Fig. 1 Station map of broadband seismograph observatories. Red dots show locations of the broadband seismograph stations. Green dots indicate planned stations in Vietnam.

2 degrees.

The strong motion seismograph and the broadband seismograph at station KSI could record the seismic waves generated by this strong earthquake. Figure 5.2 demonstrates strong motion records of this earthquake recorded at KSI. Continuous records of strong motion seismograph are transmitted to the Indonesia Meteorological Agency in realtime. The Indonesia Meteorological Agency in Jakarta used these record for monitoring aftershock activities in this area after this strong earthquake.

IFREE's geophysical network now directs toward observations by multi-parametric sensors collocated at same observatory. By using multi-parametric sensors, it becomes possible to obtain mutual interactions of various geophysical processes. In FY2007, we installed and opened a multi-parametric station at Majuro islands, Marshall Islands in Central Pacific region. Majuro is isolated island in Pacific Ocean. The manned and developed of infrastructure islands around Majuro are rare in the distance range of some thousands km. This area is one of gap areas for global geophysical network. Majuro is located beside Ontong-Java Plateau which is aimed interestedly by scientists and Solomon and Papua New Guinea are located beyond the plateau. We have operated geomagnetic station from 2001 to 2006 but the contraction of land release for our station was terminated. We considered that it was a good chance to re-install station at other location as multi-parametric station with combining of seismic observation system.

Majuro Island is consisting of atoll, so that all land is just above sea level. All sensors are installed in the bottom of verti-

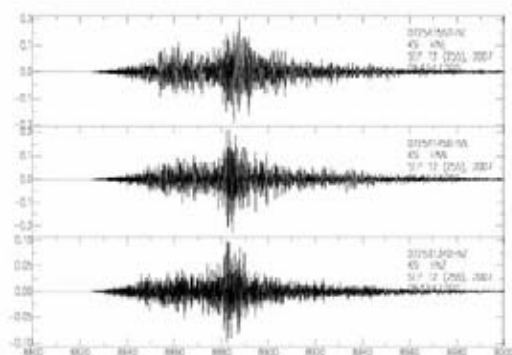


Fig. 2 Three component strong motion seismograph records of KSI for September 12, 2007 event. 200 second records are shown for horizontal east-west, horizontal north-south and vertical components from top to bottom.



Fig.3 Installation of magnetometer in Majuro (above). Construction of installation site for broadband seismometer in Majuro (bottom).

cal hole about two meters below the surface. The depth hole reaches to subsurface base layer. On the other hand, we met some problem that the sensors contact sea water by upwelling synchronized tidal sea level change. We tried to construct holes protected by marine-concrete barrier. In August, 2007, geomagnetic measurements restarted and seismic observation system was also installed in October, 2007 (Figure 5.3).

We have already had experiences about geomagnetic measurement at Majuro. It is easy to estimate data quality and to evaluate site condition. However, the condition is poor for broadband seismic observation in the sake of easy vault. According to quick data review, pen drum mass is stable which means tilting of basement is limited. Fortunately ambience temperature variation around sensor is small by tropical whether condition. The overall data quality and stability are better than our initial estimations.

We retrieved continuous data for three months and evaluated data quality by comparison with data at existed station. To analyze earth's mantle structure by ordinary technique, Majuro station is valid for this purpose. The group velocity difference between path on Ontong-Java plateau and one beside the plateau is significant (Figure 5.4). JAMSTEC has a plan to deploy ocean bottom sensors in this region. Majuro and other out network will play important position which supports this project.

Additionally Majuro station is highly detectable sensor for microseisms, T-phase and ocean origin signals. We have a plan to install telemeter equipment. Majuro station will be one of real-time and continuous monitor network for earthquakes and

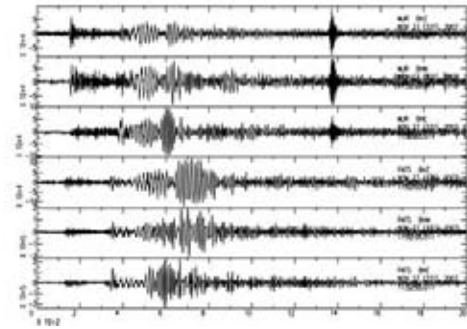


Fig. 4 Top three traces show broadband seismograms recorded at Majuro. 2000 seconds records of vertical, horizontal North-South, East-West are shown from top to bottom. Lower three traces are the broadband seismograms recorded at our Micronesia station PATS.

ocean tremor status. Data recorded in this project is open to any researchers. The data is archived in data-base system in JAMSTEC which included Web user interface.

2) Numerical simulation and database

Volcanic activity is one of the observable phenomena at the boundary between the atmosphere and the solid Earth. In order to predict the volcanic eruptions on the basis of geophysical observations such as ground deformation around volcanoes and reconstruct the historic volcanic eruptions on the basis of the volcanic sediments, we must understand dynamics of magma from a magma chamber through a volcanic conduit to eruption cloud. For this purpose, we are developing a numerical model for eruption cloud dynamics as the first step.

During explosive volcanic eruptions, a mixture of hot ash (pyroclasts) and volcanic gas is released from the volcanic vent into the atmosphere. Such events are characterized by the formation of eruption columns and/or pyroclastic flows. Generally, the ejecta (i.e., pyroclasts and volcanic gas) have an initial density of several times as large as the atmospheric density since it contains more than 90 wt% pyroclasts at the vent. As the ejecta are mixed with ambient air, the density of the mixture drastically decreases and becomes less than the atmospheric density, because the entrained air expands by heating from the hot pyroclasts. When the ejecta entrain sufficient air to become buoyant, a large Plinian eruption column rises up to a height of several tens of kilometers as a turbulent plume. On the other hand, if the ejecta do not entrain sufficient air and their vertical velocity fall to zero before the eruption cloud becomes buoyant, a col-

umn collapse occurs and the heavy and hot cloud spreads radially as a pyroclastic flow. Thus dynamics of eruption clouds is governed by (1) the density change of the mixture of the ejecta and air, and (2) the turbulent mixing in and around the eruption clouds.

We have improved the 3-D fluid-dynamics model of Suzuki et al. (2005) to exactly reproduce the above two physical properties. The improved model has successfully reproduced the qualitative features of large-scale eruption clouds such as that of the Pinatubo 1991 eruption. In addition, the qualitative agreement between the observations and the results of the present 3-D simulations (e.g., eruption column height, altitude and spreading rate of umbrella cloud as a function of mass discharge rate) validates the present numerical model. We have also successfully visualized the face structures of eruption clouds on the basis of the 3-D simulation results (Figure 5.5).

Up to the present, various geochemical and geophysical data have been produced, and most of the data have been compiled into databases. We can accumulate a large amount of various data easily and quickly from these database systems on the

Internet. Visual presentation of these various geoscience data together will be very useful for cross-disciplinary study on the Earth's interior. Each data set, however, has its own format and own presentation tool. To display the different kinds of the geoscience data together needs some procedures. In research program for data and sample analyses of IFREE, we aim to provide a method to display various geoscience data together easily and quickly.

We adopt Google Earth as a common geoscience data browser. Google Earth is a 3-D map viewer provided by Google. Google Earth makes use of an XML called KML to display graphical features over terrain view. We have developed software to convert various geoscience data to a KML file. Our project started last year. At first, we have developed the conversion tools for the seismic tomography models, geochemical data of rock from GEOROC and PetDB, which are online database, and navigation data of research vessels. Until now, we have improved these tools and added new features to them. For example, the legend of the bar graph for the geochemical data of rock came to be displayed (Fig. 5.6). Several seismic tomogra-

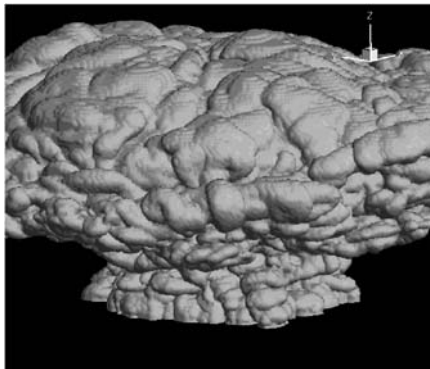


Fig.5 Numerical results of large-scale volcanic eruption clouds at 500 s from the beginning of eruption. Lateral view of the iso-surface of the mass fraction of the ejecta from the volcanic vent.

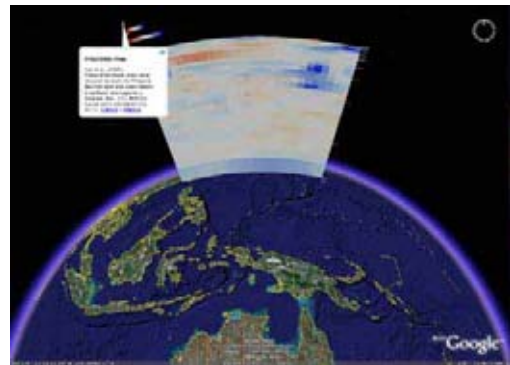


Fig.7 The vertical cross-section produced by a combination of two tomography models. The top part, from the surface to a depth of 245 km, is produced from PHS2006S-ifree (Isse et al., 2006) and the bottom part is produced from GAP-P1 (Obayashi et al., 2006).

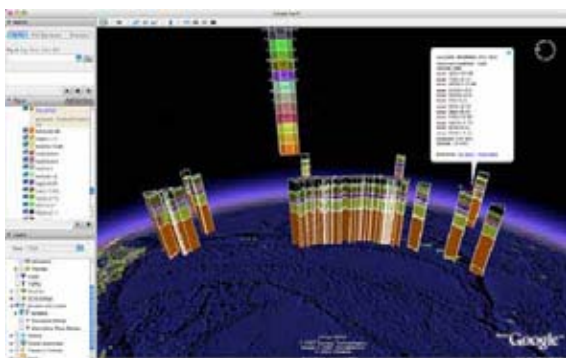


Fig 6 Geochemical data of rock sampled from Pacific Ocean from PetDB on Google Earth.



Fig. 8 The top page of the web sites for conversion tools for geochemical data of rock and seismic tomography model.

phy models can be combined to produce a vertical cross-section (Fig. 5.7). In addition, we have developed web applications of the conversion tool for seismic tomography model and geochemical data of rock, which are now available on the Internet (<http://www.jamstec.go.jp/pacific21/TMGonGE/top.html>). Fig. 5.8 shows the web site for these web applications. We started to develop new conversion tool for the other data such as geomagnetic field model, seismic data of ocean floor by a large airgun array system.

We are going to support more data format and provide these conversion tools as web application or Java application.

3) The Ontong Java Plateau - geochemistry and mineralogy of basaltic rocks from the Lyra basin

The Lyra Basin lies along the western edge of the Early Cretaceous (~122 Ma) Ontong Java Plateau (OJP), the world's largest oceanic plateau (Fig. 5.9, top). We have done geophysical and geological investigations in the Lyra Basin aboard JAMSTEC's R/V KAIREI in December 2006 to examine whether there is any relationship between this basin and the main plateau.

We obtained ~50 kg of dredged samples from two sites

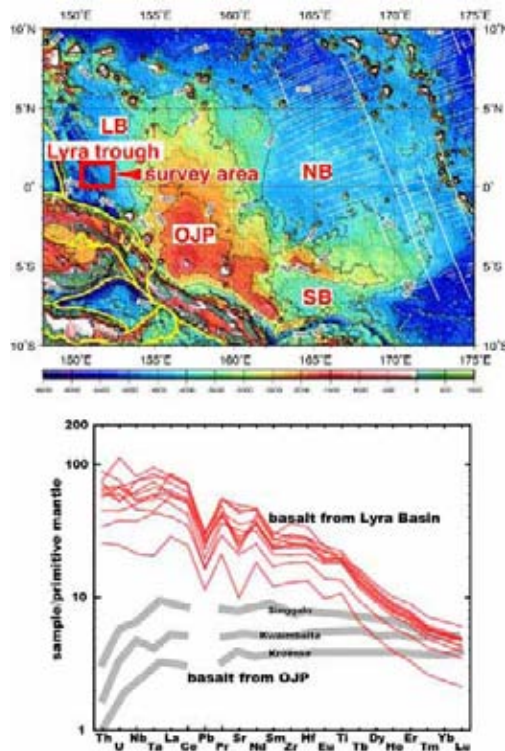


Fig.9 The Ontong Java plateau and the Lyra basin (top). Comparison of the trace element pattern for the OJP and Lyra basalts.

near the Lyra Trough, consisting of Mn-crust-coated volcanoclastics and some fresh basaltic and picritic rocks. Clast size varied from several millimeters to several tens of centimeters. Fresh fragments are olivine (Fo 78-86) - clinopyroxene (titanaugite; Wo ~45, En ~47, Fs ~8; TiO₂ ~1.8 wt%) phyric alkalic basalts with estimated liquid composition of ~46 wt% SiO₂, ~8 wt% MgO, ~4 wt% Na₂O+K₂O, and ~4wt% TiO₂, different from previously reported compositions of OJP lavas (liquid composition: SiO₂ ~ 50 wt%, MgO ~ 8wt%, Na₂O + K₂O ~ 2wt%, TiO₂ ~ 1wt%). These basaltic clasts also have highly enriched chondrite-normalized incompatible trace element patterns (La/YbN ~12), which are completely different from those of OJP volcanic rocks (~1.2) (Fig. 5.9, bottom). 40Ar-39Ar dating of clinopyroxene separates and groundmass of two fresh samples gave two different ages. The 40Ar-39Ar plateau ages of groundmass are much younger (65-70Ma) than the main OJP (~122Ma), whereas the 40Ar-39Ar total ages of clinopyroxene separates are comparable (100-130Ma) to the age of OJP emplacement.

Present data set indicates that basaltic volcanic rocks from the Lyra Basin are possibly formed by very low degrees of mantle melting long after the main eruption stage of OJP. The presence of older clinopyroxenes could either 1) represent older plateau or Lyra Basin crust, incorporated during ascent of alkalic magmas within the basin 65-70 Ma or 2) represent excess Ar of the alkalic magmas, crystallized in magma chamber around 120 Ma, co-existing with the magmas for ~50Ma until they erupted at 65-70 Ma.

4) Contrasting Os isotopic compositions between Cr-spinels of boninites and tholeiites in Izu-Bonin arc: implications for contribution of anciently depleted mantle and slab-derived component to arc magma.

Osmium (Os) isotope is a sensitive tracer of crust, because of significant contrast between a high Os isotope ratio of crust and a low ratio of mantle. Therefore, Os isotope is a promising tool to constrain slab component contribution to the mantle source of island arc lavas. Although it is suggested that radiogenic Os isotopic compositions in arc lavas are attributed to the input of the slab component to the mantle source, assimila-

tion of crustal materials during magma ascent may also elevates the Os isotope ratios of the magma. Here we report the extremely unradiogenic Os isotopic ratios ($^{187}\text{Os}/^{188}\text{Os} < 0.125$) of Cr-spinel sands from boninite islands and the highly radiogenic Os isotopic ratios (0.142) of that from tholeiite island in Izu-Bonin arc. As Cr-spinel is resistant to later alteration and weathering and, more importantly, is the early stage crystal in fractional crystallization, it preserves the isotopic compositions of very primitive magma. The unradiogenic Os of boninite Cr-spinels strongly suggests significant contribution of ancient mantle found in the area to boninite magma generation. The elevated Os isotopic composition for the tholeiites is most likely resulted from the slab-derived component with a high Os isotope ratio (Fig. 5.10)

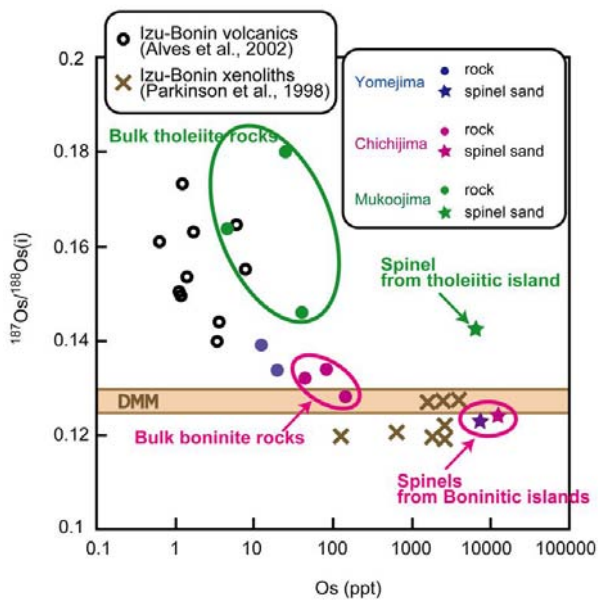


Fig. 5.10 Os isotopic compositions of Cr-spinel from boninite and tholeiite islands and bulk boninite and tholeiite rocks collected from the Bonin Islands.

1.1.4 Marine Biology and Research on Extremophiles

(1) Research Program for Marine Biology and Ecology

a. Studies on Chemosynthetic symbioses

We studied gene expression of the symbiont of a deep-sea clam, *Calyptogena okutanii*. Reductive genome evolution of this symbiont was also studied. In the study of animal-microbe communities on whale carcasses, we found that a symbiotic mussel, *Adipicola pacifica*, was relatively easily kept in the laboratory aquaria with whale bones. We established methods to remove the symbiotic bacteria from this mussel, and to reinfect them to the mussel. We believe that this mussel is promising for future studies on the mechanisms underlying symbiosis

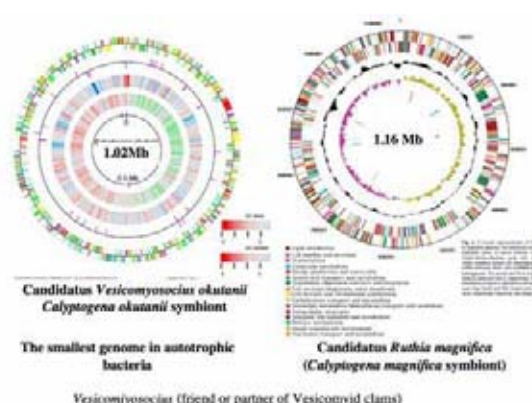


Figure 1 Genomes of two symbiotic bacteria of *Calyptogena okutanii* and *Calyptogena magnifica*

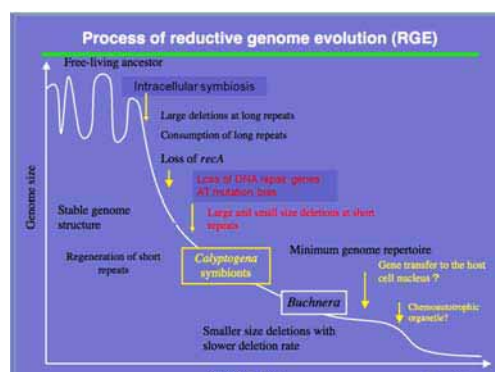


Figure 2 Reductive genome evolution in *Calyptogena okutanii*

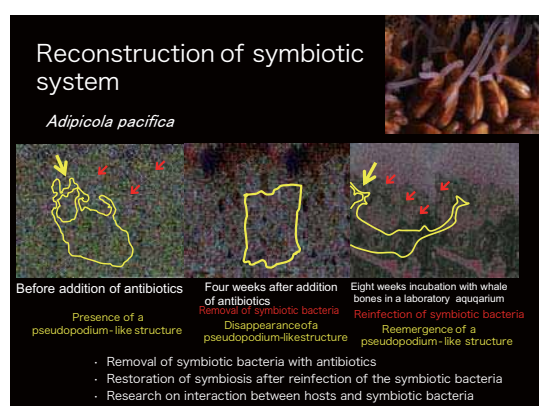


Figure 3 Reconstruction of symbiotic system in *Adipicola pacifica*

between deep-sea host animals and their symbiotic microorganisms.

b. Research on changing Marine Ecosystems

b-1. Marine Plankton Research

In investigation of the zooplankton at the K2 station in the northwestern Pacific Ocean, zooplankton was collected with a large scale plankton net (IONESS system). Feeding pressure of the zooplankton on producers, microalgae, was measured on board. It was shown to reach 60% of the primary production.

By these studies, we are getting to understand the structure (community structure, biomass and diurnal vertical migration) and functions (carbon transfer by a biological pump and feeding pressure in the zooplankton) of zooplankton in marine ecosystem in this area (Figure 4).

b-2. Search for new Chemosynthesis Based Ecosystems

Relation between distribution of constitutive organisms with environmental conditions was mainly investigated in a hydrothermal vent zone, a methane seepage zone and middle and deep layers in sea area of the Sagami Bay, Izu Islands and Ryukyu Islands.

We searched for a new animal communities based on chemosynthetic symbiosis in hydrothermal vents, methane seeps of the Sagami Bay, Izu Islands, Ryukyu Islands and Taiwan coastal area. We found a new such community during the cruise at the methane hydrate zone off the southwest coast of Taiwan, where we found a dense community of *Shinkai crosinieri*. This species has chemosynthetic symbionts and has been considered to be specific to dwell in the hydrothermal vent area.

b-3. Development of Untethered Remotely Operated Vehicle (UROV) for biological research

A test cruise was taken for technical assessment of UROV,

Composition of microzooplankton in surface waters at K2 station and feeding rate in the dominant species *Neocalanus copepods* (during the cruise of MR06-03)

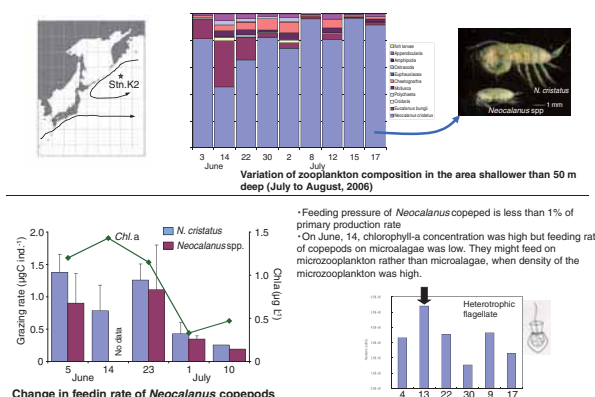


Figure 4 Change of plankton composition and feeding rate of zooplankton at the K2 station

"PICASSO" equipped with high definition TV camera system and/or visual plankton recorder, (in Sagami Bay, Tokyo Bay, etc.). A test cruise of the autonomous underwater vehicle (AUV), "Urashima", was also undertaken for an environmental survey (in Okinawa Trough) with chemical sensors and acoustic exploration devices (Figure 5).

c. Book publishing

We published a book, "Deep-sea Life - Biological observations using research submersibles" with 512 pages and a size of B5 from Tokai University Press, which is the first textbook for deep-sea biology in Japan. We also published a picture book, "Great adventure of the earth by ship named as Whale", which is presented to all children and adults with child's mind (JAM-STECH BOOK).

(2) Extremophiles Research

In extremophiles research program, following studies were promoted to clarify a life process under extreme environments.

a. Analysis of samples in core drilled off the coast of Shimokita Peninsula

a-1. Scientific approach to genome

A complete nucleotide sequence of the rest 50 clones among 150 clones randomly selected from a fosmid library pre-

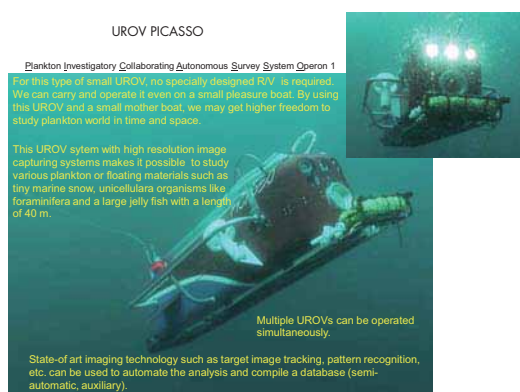
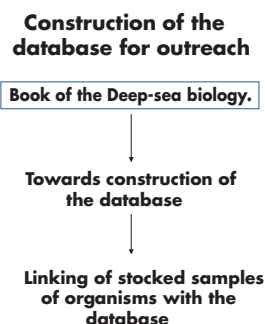


Figure 5 UROV, "PICASSO", for biological observation



Figure 6 Outreach



pared from a microbial mat in a subsurface hydrothermal system in the gold mine was determined after analyzing 100 clones in 2006 FY. DNA was extracted from core samples from 8 layers up to 360 m depth from seafloor collected at the offing of the Shimokita Peninsula. The nucleotide sequence of 2000 clones of archaeal 16S rDNA amplified by PCR with the DNA isolated from each core was determined. A shotgun library was constructed for part of the layer and its sequencing is currently in progress. A DNA amplification method in the layer where only trace of DNA could be detected was further examined and the amplified DNA was successfully detected by its method. (Figure 1).

a-2. Approach aiming at industrial application

Phylogenetic analysis of aerobic bacterial isolates from core samples collected by ocean drilling at the offing of the Shimokita Peninsula was done and revealed that a dominant species was different depending on the depth of core sample. Also it became clear that each species has its own habitability in separate zone. Various enzymatic activity produced by 550 bacterial isolates were investigated by several assay methods with agar plates and synthetic substrates. Consequently, there is

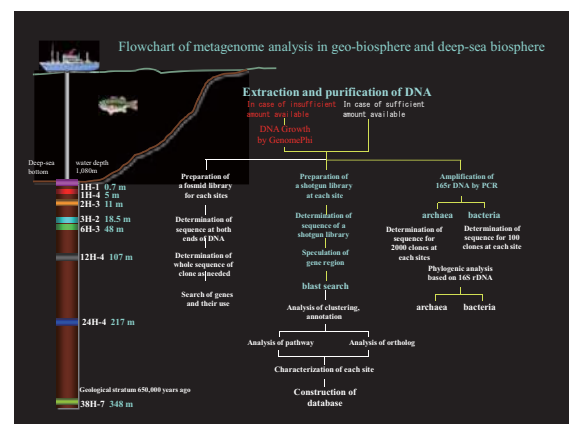


Figure 1 Flowchart of metagenome analysis in geo-biosphere and deep-sea biosphere

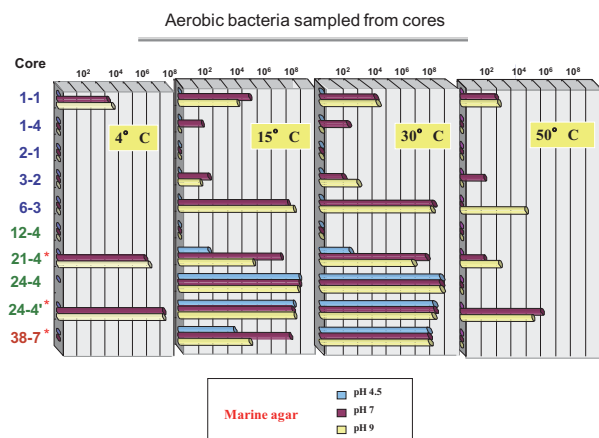


Figure 2 Aerobic bacteria sampled from cores

Enzyme-producing isolates										
Core	Number of isolate	Number of enzyme-producing isolates								
		protease	amylase	CMCase	xylanase	alginate	phosphatase	chitinase	lipase	DNase
1-1	69	35	26	5	2	4	56	20	41	44
1-4	4	3	3	1	0	0	3	1	3	1
2-1	9	0	4	0	0	0	1	0	4	0
3-2	16	1	2	0	1	0	15	0	11	1
6-3	54	2	13	3	5	0	27	3	18	15
12-4	5	5	5	1	0	0	5	2	2	4
21-4*	94	13	34	3	0	0	58	7	54	8
24-4	89	2	30	1	1	0	54	0	41	5
24-4*	68	13	32	0	0	0	47	18	40	18
27-6*	15	0	13	3	3	0	12	0	10	1
38-7*	76	0	50	9	0	0	48	1	47	1
Total	499	74	212	26	12	4	326	52	271	98

Figure 3 Enzyme produced by separated bacteria

no significant difference in kinds of enzymes depending on the depth from seafloor. As other achievement, a new substrate recognition domain-like sequence was found in collagenolytic enzymes. Effectiveness of the host-vector system is currently being confirmed in a collaborative research project with a private company. We also successfully increase thermostability of sucrase dramatically. A technology of producing a thermostable agarase was provided to a private company (Figure 2 & 3).

b. Research on adaptation of organisms to high pressure

Among 4800 genes after functional analysis, 80 genes essential for growth under high pressure and low temperature were identified. Among them, 40 genes were found to have genetic and physical interaction and indicate the presence of a network within a cell. A lifetime of overall fluorescence could be measured and a condition to collect good data could also be set for measuring a lifetime of polarized fluorescence (Figure 4).

Fishes inhabited in the middle and deep layers where vigorous vertical motion occurs in this biotope were captured alive and their cell culture was initiated. Various culture conditions were set and primary culture to subculture is in progress. Cell

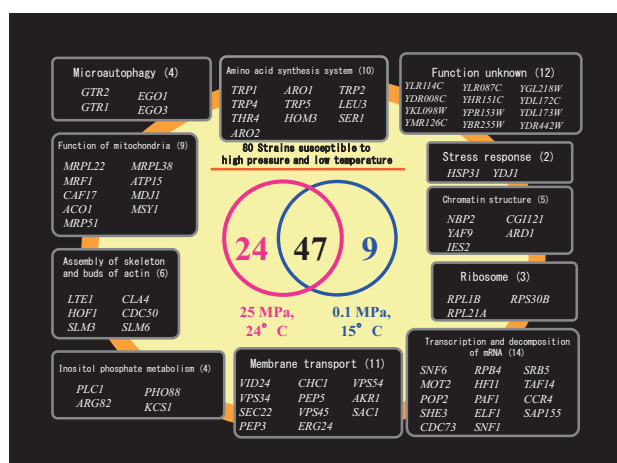


Figure 4 80 Strains susceptible to high pressure and low temperature

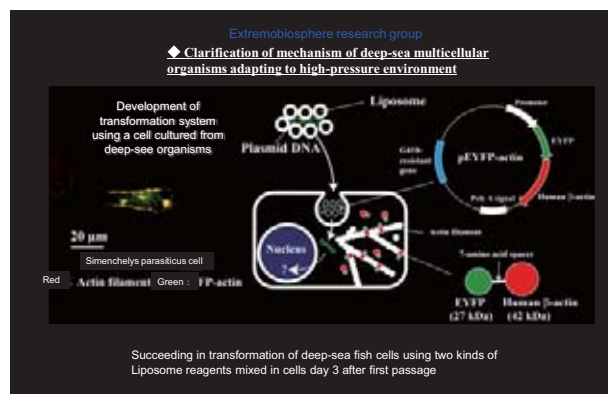


Figure 5 Adapting mechanism of deep-sea multicellular organisms to high pressure environment

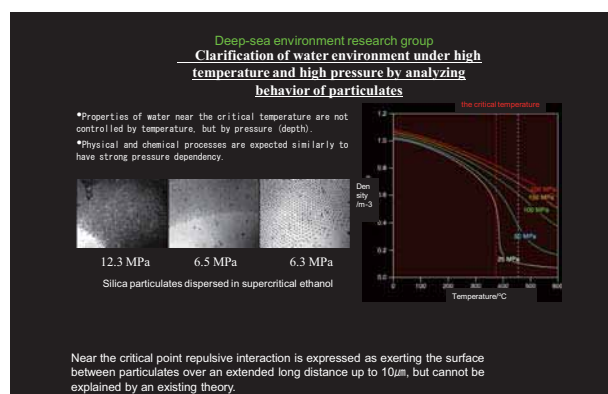


Figure 6 Water environment under high temperature and high pressure analyzed by behavior of particulates.

culture of shellfishes was also performed and branchial cells of Bathymodiolus sp., a kind of chemosynthetic organisms in deep sea, and their immune cells were successfully cultured under atmospheric condition A procedure for a genetic engineering into cells derived from deep-sea chemosynthetic organisms was also established (Figure 5).

c. Physicochemical research

A new experimental apparatus was designed with which a sample can be treated in supercritical water at temperatures and pressures up to 450 °C and 100 MPa, respectively. Our high-temperature and high-pressure optical microscope system was also modified so that detailed studies can be performed on anomalously long-range repulsion that appears between silica surfaces in supercritical ethanol in the vicinity of the liquid/gas critical point. (Figure 6)

(3) Deep subsurface extremophiles research

a. Discovery of extremophiles in fertile deep subsurface

Various aerobic bacteria from cores off the coast of Shimokita Peninsula were successfully separated and quantified to prove the presence of microbial community active in a deep subsurface. It was shown that a very large number of active microorganisms exist particularly in a layer of sand and volcanic ash containing methane hydrate.

b. Development of a culture method using regenerated field circumstance

"Culture method using regenerated field circumstance" and "Bioreactor method based on environmental engineering" were developed as a new procedure to culture unknown microorganisms inhabited in environment of deep sea and deep subsurface to succeed culturing such microorganisms, which were historically unable to separate. In addition, many new microorganisms were successfully separated by a conventional method.

c. Development of gene source from deep subsurface extremophiles

Metagenome analysis of microbial community in a land mine plant was continued to estimate the genome structure derived from unknown and uncultured deep subsurface extremophiles including Archea and its genetic function and find the presence of complex ecosystem of unknown genes (Figure 3) .

d. Clarification of energy in deep subsurface ϵ -proteobacterium strains

Genome of deep subsurface ϵ -proteobacterium strains was analyzed and symbiotic mechanism with chemosynthetic organisms was considered first time at a level of molecular biology to clarify the presence of complex energy metabolism system held by these bacteria.

We clarified that different anaerobic methane-oxidizing microbial communities were separately inhabited in surface deposits in a cold seepage zone of the Nankai Trough depending on the depth. Further, a nitrogen metabolic system of these microbial communities was identified first time at a level of RNA (Figure 4) .

Original idea is by Thom and Marquis, 1984.

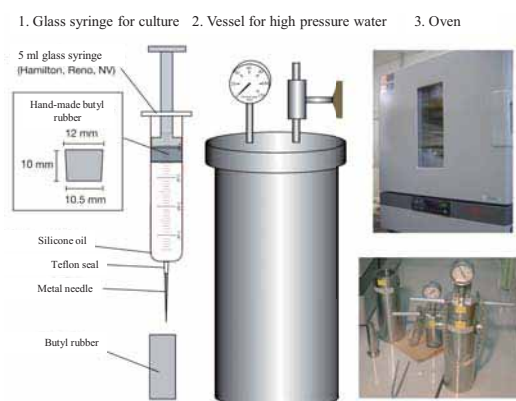


Figure 1 Schematic diagram of a newly developed culture method using regenerated field circumstance (Takai method).

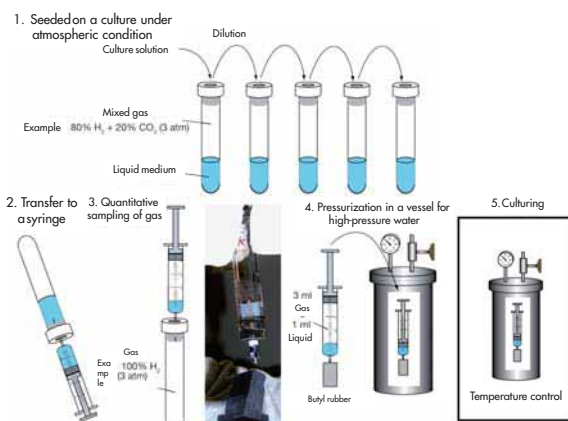


Figure 2 Procedure of culture method when regenerating the field circumstance.

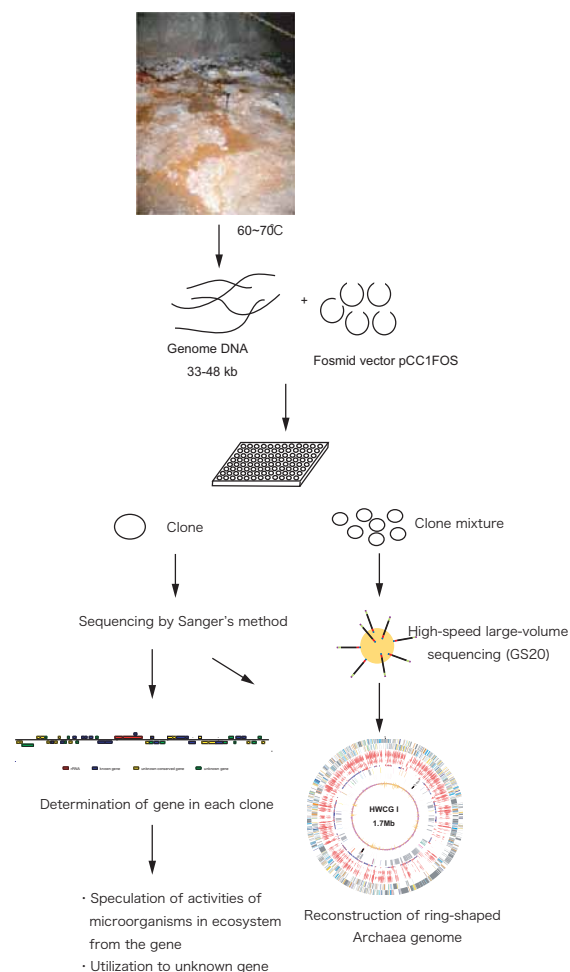


Figure 3 Analytical method of metagenome in Hishigari gold mine.

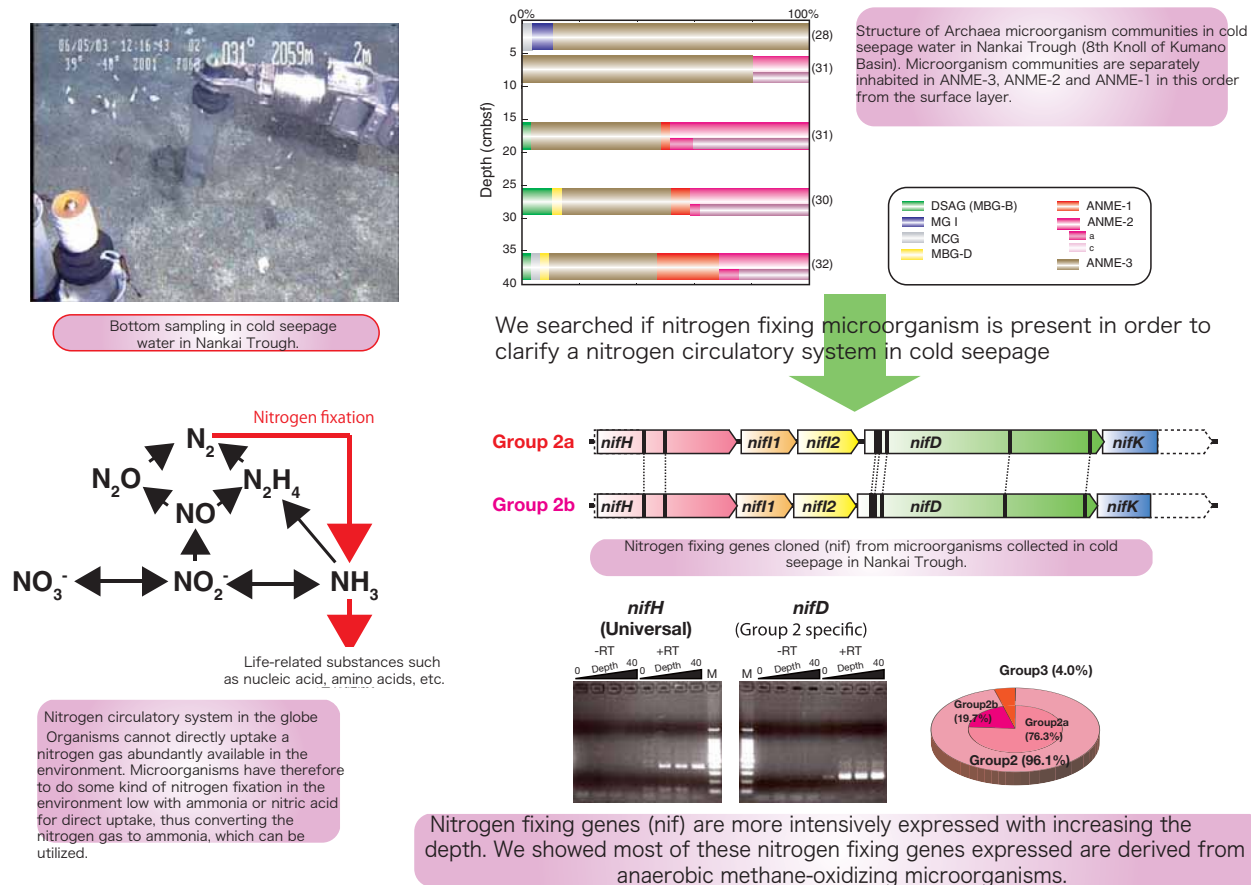


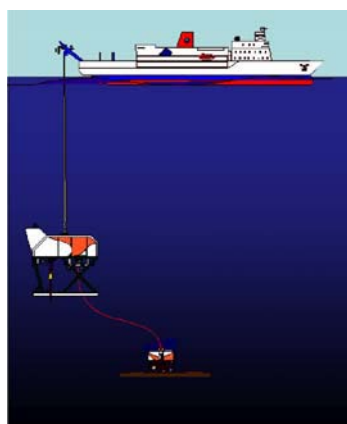
Figure 4 Search of nitrogen fixing microorganisms in cold seepage water in Nankai Trough.

1.2 Promotion of priority developments

1.2.1 Research and development of fundamental technology in the ocean research field

(1) Development of technology for an advanced submarine research vehicle

We conducted the development of constituent technologies and higher functionality for an advanced submarine research vehicle capable of conducting surveys, observations and similar at deep depth of 11,000 m



Conceptual diagram of a unmanned remotely-controlled submarine research vehicle

① Development of technology for a high-strength deep-sea cable

a. Prototyping of a small diameter cable

Newly developed tensile materials (fibers developed were converted to a form of FRP rod) were used to make a prototype of small diameter cables with a new structure.

b. Fatigue testing of a cable under high pressure

Using an accelerated fatigue tester two kinds of the prototyped small diameter cable (tensile materials: composed of conventional fibers vs. newly developed fibers) were compared in strength retention by conducting an accelerated fatigue testing including a 1000-cycle test of the axial-torsional loading, a



Cables being developed



Accelerated fatigue testing

cyclic tensile test, an S-shaped ironing test and a U-shaped ironing test, thus confirming usefulness of the fibers developed.

② Development of technologies for high-strength buoyancy material used at water depth of 11,000 m

a. Pyrogenic properties of high-strength resin

The distribution of temperatures in a high-strength resin cured is varied with various points because of a thermoset resin. In particular, when a size of a formwork for molding is increased, microballoons (hollow glass spheres) retain the heat to increase the temperature at the center of formwork and curing the resin inside the formwork causes cracking at interface with the microballoons. We determined pyrogenic properties of the resin inside the formwork for understanding by heat measurements.

b. Prototyping and evaluation of buoyancy material by temperature-controlling method

A method of controlling the temperature inside the formwork was developed and a medium-size formwork (volume, 18L) was prototyped, in which a prototype of our buoyancy material was molded to compare with the conventional product and foreign commercial product by testing under high pressure and determine the stress-strain curve for quantitative evaluation, thereby confirming the buoyancy material prototyped by means of the temperature controlling method was not broken at pressure of 146 Mpa.



Buoyancy product developed by JAMSTEC



Overseas commercial buoyancy product

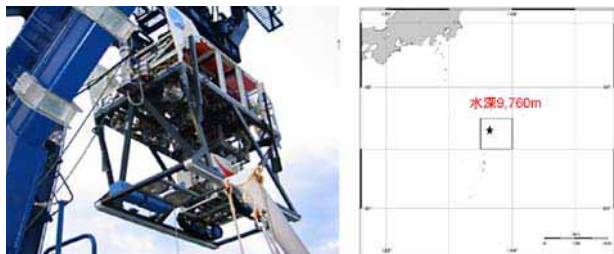
③ Development of high speed optical communication system

An underwater fiber optic rotary joint for deep depth used in an optical fiber communication system (single-mode fibers) was developed, since the rotary joint has high optical loss under high hydraulic pressure because of a small diameter of the optical fibers and the rotary joint with low optical loss is currently unavailable as well as a system of following the rotation of the

rotary joint has to be developed because the fiber optic rotary joint is revolved with the motion of a launcher and a vehicle. A fiber optic rotary joint for deep depth was designed and prototyped to measure stress of the optical fibers as hydraulic pressure was applied stepwise up to 122 Mpa.

④ Manufacturing and testing of prototyped survey equipment

We developed a small unmanned remotely-operated vehicle, "ABSIMO", (Automatic Bottom Inspection and Sampling Mobile, which means the deep chasm in Spanish), on which survey components were installed for testing and let ABSIMO descend twice in the vicinity of the ocean floor in order to confirm their technologies for sophistication. We reached in December, 2007 the submerging depth of 9,707 m in the sea region approximately 9,760 m deep in the deepest section of the Izu-Ogasawara Trench. This submerging test allowed us to confirm the performance of the unmanned remotely-operated vehicle, which is capable of submerging deepest among unmanned remotely-operated vehicles currently available in the world. This submerging test also showed a potential to submerge approximately 11,000 m deep, the depth corresponding to the deepest section in the world.



Automatic Bottom Inspection and Sampling Mobile, ABISMO

Sea area for testing

(2) Development of technology for autonomous underwater vehicle

We intended to improve the performance of the autonomous underwater vehicle (AUV) while provided for ocean observation as well as lengthen its cruise distance.

① Navigation system

A control algorithm, which allowed autonomous navigation of the AUV at a certain altitude above the ocean floor essential for a survey of the high-precision ocean bottom topography was built in the AUV to test its movement under the sea and the operational behavior of survey components. A mathe-

matical model, which becomes the basis for designing a control system to improve the control precision was also constructed to identify the navigation system using the data of movement experimentally obtained so as to reflect the actual movement of the AUV.

② Research on a closed-type fuel cell system

The circulation system such as the gas circulation system, the process for separating the produced water from circulated gas and the like have to be studied in order to prolong the period of power generation and increase the capacity in the fuel cell system. We prototyped the recovery system of unreacted gas discharged from this stack for its effective use in the closed-type fuel cell system and evaluated its performance. We also extracted parameters required for designing the fuel cell system for extended power generation based on the data obtained through simulation, etc.

③ Ocean testing

Since FY 2005, we conducted engineering tests for stable cruise of the AUV by approaching to the vicinity of the sea floor in order to achieve precise measurement of the deep-sea floor. In FY 2007, we allowed the AUV to approach from the vicinity of the flat surface to rough surface of the ocean floor, measured its movement, and collected the data measured with the survey components installed on the AUV.

In May, July, and February, we conducted ocean testing of the AUV in the Kumano Trough off the coast of Mie Prefecture, the sea region near the North Iheiya Island of Okinawa and the Sagami Bay. The AUV was navigated at a certain altitude above the bumpy ocean floor to examine its movement characteristics and tune the altitude control of the AUV as well as collect the data of its movement as the basic performance of the navigating AUV. The AUV was approached to the vicinity of the ocean floor to simultaneously collect the data on the ocean floor, allowing us to acquire high resolution bathymetric charts in hydrothermal vent ores and acoustically measure hydrothermal eruption at vents. Synthetic aperture sonar processing was applied to a conventional sonar installed on the AUV URASHIMA to successfully improve the azimuth resolution (resolution in travel direction) in a range of 300 m approximately from 6 m to 2 m as well as a new algorithm for

the synthetic aperture algorithm (algorithm for combined compression, filed for the Patent Application) was used to confirm in a simulation test the amount calculated by a computer required for generation of a sonar image can be reduced less than one tenth that obtained by a conventional algorithm while maintaining the high resolution of the image.

In order to improve the operation and maintenance of the AUV in real operation, we replaced a current main secondary cell with a fresh one, renewed a stabilized power source and simplified a ballast system.

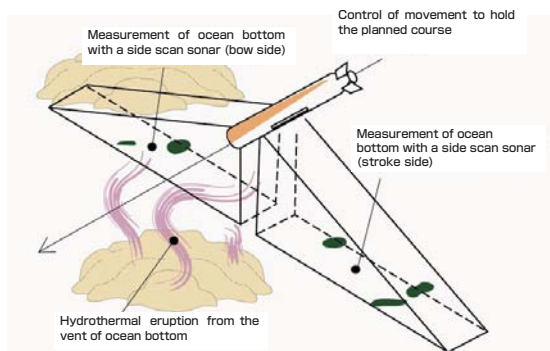
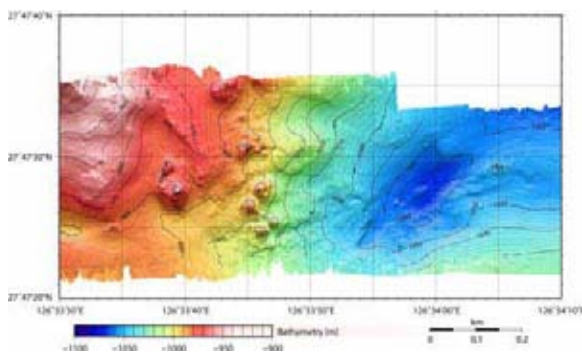


Diagram of imaging the measurement of cruising characteristics of the AUV and precise survey image of ocean bottom topography



High precision bathymetric chart in the sea area of hydrothermal erupting vents near the North Iheiya Inland of Okinawa



Continuous acoustic image of ocean floors near the sea area of hydrothermal erupting vents near the North Iheiya Island of Okinawa

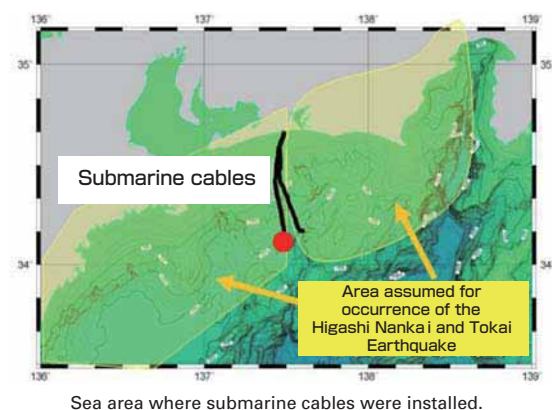
(3) Development of technologies for a comprehensive seafloor observation network system

① Development of an observatory reusing of submarine optical telecommunication cables laid off Toyohashi

For the purpose of reusing about 60 km long submarine optical telecommunication cables, which were transferred from KDDI Corporation to the JAMSTEC and were laid off the coast of Toyohashi, for scientific observation through development of the key technology for seafloor observation network, we developed technologies of the power supply to submarine cables, data transmission, time synchronization, etc. and attached the branching unit provided with these functions in March, 2007 at the end of the western cable of above mentioned cables. During FY 2007, we conducted the system validation with emphasis of these functions as well as developed two kinds of observation instruments which were connected with the observatory and started observation. Since these submarine cables are laid in the zone where the next Tokai earthquake is anticipated to occur, they are significant in terms of geophysical observation.

② Development of key technology for submarine observation network

We conducted the validation of the observation network system with emphasis on functions of the power supply, data transmission and time synchronization provided to the branching unit, which was developed unit FY 2006 and linked with the cable system off the coast of Toyohashi. Specifically two kinds of observation instruments were connected with the cable system in April, 2007 to confirm normal operation in each functions yielding the observation data. The observation data were transmitted to the data center at the Yokohama Institute for Earth Science to start long-term observation. Since then data



sent from these observation instruments have been collected so far.

a. Technologies for power supply utilizing cables

We confirmed stable electric power was continuously supplied for long terms to the observation instruments connected to the branching unit. We also developed a controller of electric power, in which a power supply current is allowed to fluctuate at low frequency and the optical telecommunication cables can be used as an ultra-large transmission antenna of low frequency electromagnetic waves. Through the use of this device for electromagnetic observations, we may realize estimating the structure of the electric conductivity beneath the seafloor, that is, the distribution and time fluctuation of the moisture content in deep subseafloor, which is strongly related with earthquake occurrence. We plan to connect this device with the underwater cables system off the coast of Toyohashi in FY 2008 and to conduct the operational test.

b. Technologies for data transmission

We confirmed the data are normally transmitted from the observation instruments connected to the branching unit and the observation devices are normally controlled. Data are transmitted from the observation instruments to the branching unit through the RS422 serial communication interface and converted by the branching unit to the IP packet transmission over Ethernet to transmit to the land-based station. The IP-VPN access line was further connected between the land-based station and the Yokohama Institute for Earth Science, at which communication with the branching device including the control of the serial communication and the transmission of observed data was realized.

c. Technologies of time synchronization

On the time synchronization, we confirmed the precision of clock signals is better than ± 1 nsec in a stand-alone unit on land in FY 2007, however it is necessary to evaluate the precision and stability of a whole system including long-distance submarine cables. We used the loopback mode with the branching unit for long-term measurement of an amount of fluctuation in the clock signals for the precise time synchronization for four months and thereby confirmed the amount of fluctuation was less than ± 2 nsec. This assures higher precision can be kept by

more than two orders of magnitude, while this precision is required for future observation with this system such as an ocean floor tectonics measurement system using the observation sensors.

Development of observation sensors

We developed two kinds of observation instruments, a seismometer with high-precision hydraulic pressure gauge (S-SMAD) and an instrument of geomagnetic and electric field observation (DOMES), connected via an underwater matable connector with the branching unit of the observatory off the coast of Toyohashi through the dive cruise, in which the unmanned remotely-operated vehicle, “HYPER-DOLPHIN” was submerged in April, 2007 and initiated a long-term continuous observation. In this observation, earthquake occurred within the zone of an assumed focal area in the Tokai Earthquake and similar were detected.



Observation sensors installed off the coast of Toyohashi

③ Operation and utilization of observation system

Operation of the observation system off the coast of Toyohashi was initiated in addition to the operation of the comprehensive deep-sea observatory off the Hatushima Island in Sagami Bay, and the comprehensive deep-sea seismic observatory off Muroto Cape, and the one off Kushiro and Tokachi installed in series since FY 1993. As continued from previous fiscal years, we collected and analyzed the real-time data of each observatory, transmitted the observed data of seismic waveform to the Japan Meteorological Agency, etc. and disclosed the data on the web. Existing communication lines in delivering data to the Japan Meteorological Agency, etc. were consolidated for reduction of communication cost.

Development of key technologies for submarine network

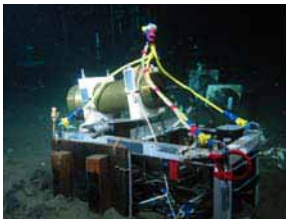
We replaced in September, 2007 a power supply equipment in the mobile observation equipment constituting part of

the observation system off Kushiro and Tokachi with a new one since it came to the end of its life and resumed the observation with a broadband seismometer and a high precision hydraulic gauge connected with the mobile observation equipment.

④ Development of observation instruments

Development of underwater LED light source

A lifespan of a light source is very important issue for the acquisition of images from the seafloor for a long period of time. The long lifespan underwater light source using an LED element, which was developed to solve this issue and connected with the observatory off Kushiro and Tokachi in June, 2006 has been continuously used for observation of the seafloor. In addition to this light source, we developed an approximately 5W LED light source with low power consumption to reduce the power consumption by approximately one twentieth and connected with the observatory off the Hatsushima Island during dive cruise in January, 2008 with the unmanned remotely-operated vehicle “HYPER DOLPHIN” for connection.



Underwater LED light source



Underwater image

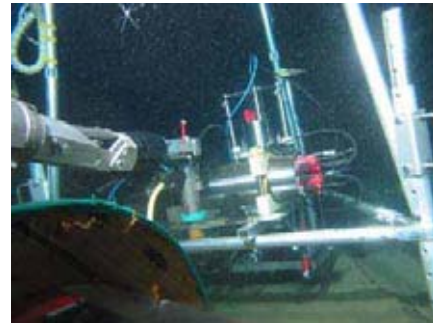
a. Testing of observation instruments for long-term measurement of two dimensional distribution of oxygen concentration (Optode sensor)

After a short-term observation testing in FY 2006, the observation sensor for two dimensional distribution of oxygen concentration (Optode sensor), which was developed at IFREE was connected in January, 2008 with the observatory off the Hatsushima Island and modified for long-term observation and a test was initiated to find its capability for a long-term observation.

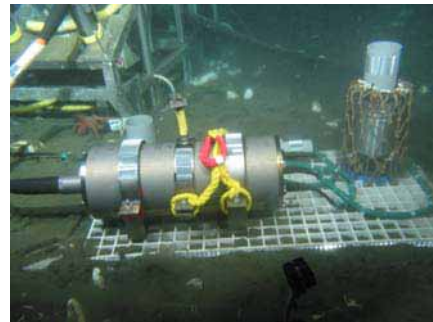
b. Observation test of a seismometer/hydraulic pressure gauge system (LINUX-BOX), etc.

The seismometer/underwater pressure gauge system (LINUX-BOX) was connected with the observatory off Hatsushima Island in January, 2008 to start continuous observation.

c. Review of evaluating installed environment and installation



Observation sensors off the Hatsushima Island



Observation system for a seismometer/hydraulic pressure gauge

procedure of ocean-bottom seismometer

With an objective of reducing background noises by bottom current and soon affecting the observation with a ocean-bottom seismometer, we comparatively measured the effects of installed environment such as the shape of the seismometer housing (spherical or cylindrical shape) and the seismometer being buried or unburied on seafloor sea area confirming the superiority of the environment of burying the seismometer to the one being unburied by field experiment. As an installation procedure realizing the environment of burying the seismometer, a benchmark procedure for the ocean-bottom installation was developed using an ocean-bottom coring system, with which the ocean-bottom seismometer was installed and tested on seafloor to confirm the environment being buried is possible.



Ocean-bottom seismometer installed

⑤ Development of cable extension technology

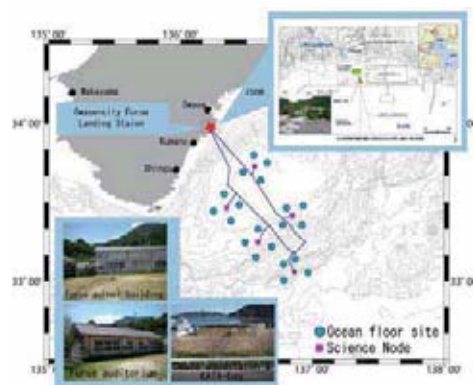
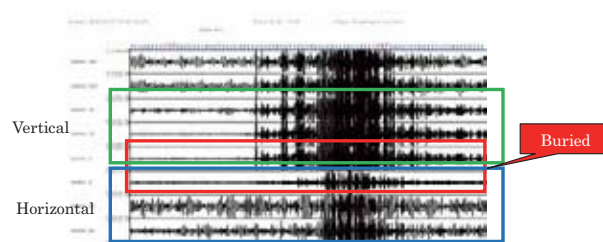
Observation devices have been required to configure densely in order to improve the accuracy observed with the ocean-bottom cable system. The cable extension technology is the most useful as a means of effectively configuring the observation devices in a form of two dimensions, but traditional cable extension technologies did not use the deep-tow technology so that they had difficulty responding to a complex ocean-bottom topography, interruption and restart of its operation caused by foreign factors such as weather and others and recovery of the ocean-bottom cables. To overcome these problems, we continued from FY 2007 the development of a cable extension device capable of boarding on the unmanned remotely-operated vehicle (ROV).

⑥ Development of off-line observation technology taking advantage of holes drilled into deep-sea floor

We evaluated the performance of both a broadband seismometer and an inclinometer in the drilled-hole as the measurement system used in the drilled-hole. The broadband seismometer in the drilled hole was installed on the ocean-floor in the Sagami Bay to evaluate the noise, whereas the inclinometer in the drilled-hole was installed on land to evaluate the noise and response to earthquakes.

⑦ Construction of observation system for earthquakes and tsunami

In order to construct an ocean-bottom network system of realizing the real-time observation of undersea seismic activities in detail and with high-precision using the advanced technologies, we prototyped and evaluated branch cables for power supply, a branching device for cable extension and the like and selected observation sensors as well as manufactured components for backbone cables and an underwater detachable interface unit. We also selected possible sites for landing the cable, investigated a land route as well as an ocean route for laying the cable and constructed a straight line diagram, which is a basis of an engineering drawing for the construction of the ocean-bottom network system.



Ocean-bottom optical communication network system

(4) Development of advanced ocean technologies

We have studied and developed the advanced key ocean technologies using cutting-edge technologies in information and telecommunication, materials and others., which are not only mutually required for the development of ocean research equipment, but also lead to commercial application in future.

① Research on structural components for oceanographic equipment

We did a test design of a pressure-resistant container using the composite material of an aluminum alloy with a new carbon-based material as a base member and evaluated its strength such as stress and the like by numerical analysis as well as prototyped a hybrid pressure resistant container for test. We also prototyped test specimens composed of the composite material to evaluate the mechanical strength by the tensile test. A magnesium alloy had the specific strength of 1.4 folds higher than a titanium alloy. We presented three papers in domestic and overseas academic conferences and filed for one patent application.

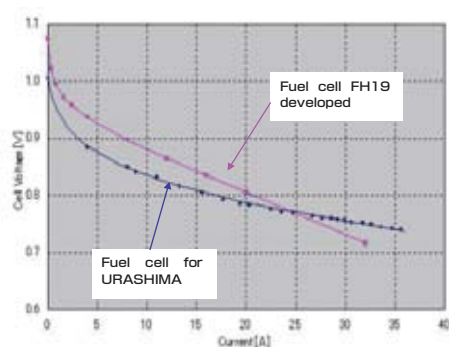
② Research on power source

We developed a new structure of electrodes, electrolyte membranes and the like for a fuel cell using nanocarbon materi-



Prototyped hybrid pressure resistant container

als and nonwoven fabrics. Film thickness was increased to 175 μ m enabling reduction of the reaction overpotential by cross leak and an amount of platinum supported was increased enabling increase of the electrochemical reactivity. This resulted in decreasing the current density in the high-current region, but enabled increasing the efficiency in low-current region, thus realizing the efficiency of 56% at operating point. In order to evaluate the efficiency of power generation, a Japan Automobile Research Institute (JARI) standard cell and an evaluation equipment were prepared to compare the performance of the prototype cell. After considering about boarding on a research vehicle, we tested a stacked form of the fuel cell for higher reliability, power saving and miniaturization of the system. We designed a power generation system without blowers for miniaturization of the system and conducted a basic test. We presented three papers in academic conferences.



Comparison of characteristics of fuel cell I-V

③ Research on underwater acoustic technologies

In order to realize high speed underwater acoustic communication, we modified the receiver, measured the communication characteristics in an experiment in the real sea area and confirmed a communication rate of 80,000 bits/sec can be realized over a transfer distance of approximately 500 m. We further developed part of a program for the real-time operation of the demodulator circuit. We conducted an experiment on the acoustic wave propagation over a distance of 100 km in the

sound fixing and ranging (SOFAR) channel for the long distance acoustic communication by the phase conjugate wave and demonstrated pulses are converged by applying the passive phase conjugation processing.



Image after demodulation (color resolution, 320 x 225 pixels; transmission distance, 510 m; transmission time, approximately 0.9 sec.; no error)

④ Research on measurement and sensor technologies

An inertial navigation system (INS) measures the travelled distance with an accelerometer and the direction of movement with a gyroscope so that it calculates its position based on motion sensors in time-series. The INS determines the cumulative distance travelled so that it has a problem, in which its measurement error is cumulative with time to substantially deteriorate the accuracy in measuring its position. We developed the system with reducing the measurement error to improve the accuracy of the INS and evaluated the precision of tracking its position. We also constructed a control system for rotation of the INS capable of mounting on a mobile vehicle and tested it on land.

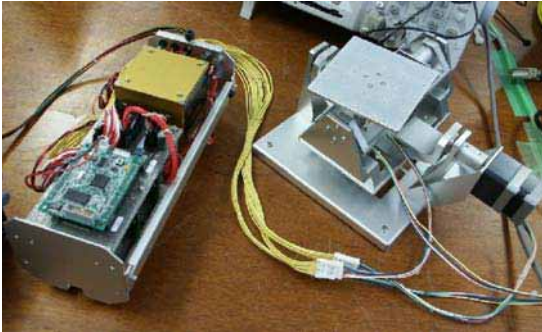


Comparative evaluation of INS on a mobile vehicle

⑤ Research on remote control of oceanographic equipment via satellite

Since a satellite Kiku No. 8 of Japan Aerospace Exploration Agency (JAXA) failed in uplink transmission because of troubles with satellite communication channels, the

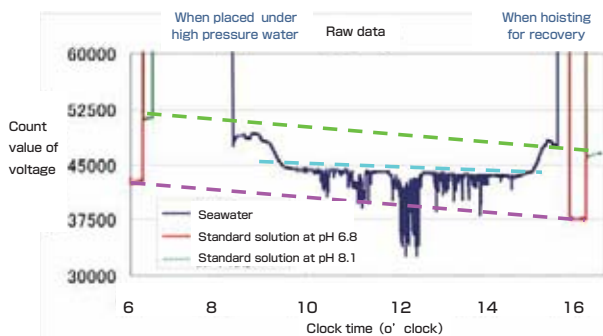
system of consolidating the new antenna using artificial muscles prepared in FY 2007 with a tracking instrument became unusable. We then established an alternative test method (gap filler method) in cooperation with the Ministry of Internal Affairs and Communications and the National Institute of Information and Communication Technology (NICT). We developed a new on-board instrument for transmission control, since the gap filler method uses a land-based relay station for uplink transmission and short-distance transmission with the land-based station is required. Additionally, we are currently developing communication antennas for communication with the land-based relay station. We presented one paper in an international academic conference.



On-board instrument for transmission control developed

⑥ Research on environmental measurement technologies

We developed and evaluated a compact pH sensor effective under high pressure water and excellent in response using an ion-selective field-effective transistor. In preliminary evaluation it showed the pH anomaly due to hydrothermal plumes (good response), but exhibited drift characteristics before placing under high water pressure and after hoisting for recovery and we examined the correction function of the pH sensor at site using a microfluid device.



Time series graph of raw data in a compact pH sensor (drift characteristics)

1.2.2 Simulation research and development Earth Simulator Center

(1) Computational Earth Science Research Program

Regarding the atmosphere ocean simulation research group, the improvement and high resolution simulation of AFES (atmosphere) and OFES (ocean) which are global atmospheric oceanic connection model CFES and that component were done. Three examples are introduced below concerning the predictability of remarkable phenomenon and connection phenomenon of the improvement and the atmospheric ocean of OFES which was done in 2007 business year and the research of elucidation of mechanism. With OFES which is the oceanic part of CFES, when depth of mixed layer of the subarctic region of winter, compares with observation, it was shallow, reproducibility of the sub-surface and the mode water was low. Then, the vertical mixed scheme of Noh and Kim (1999) was introduced for reproducibility improvement of mixed layer, anew. This scheme is improved seeking turbulent motion energy, with the scheme which diagnoses spread coefficient of viscosity, sea surface boundary condition considering the microstructure of oceanic top. The sensitivity experimental result of OIFES of 0.25 degrees is shown in Fig.1, but, as for the result of new scheme, when it compares with the case of the KPP scheme which has been used until recently, as for mixed layer distribution of winter in the subarctic limits we have become deep, shallow in the Kuroshio current dynamic current limits, distribution of mixed layer depth became realistic depending upon the introduction of new scheme.

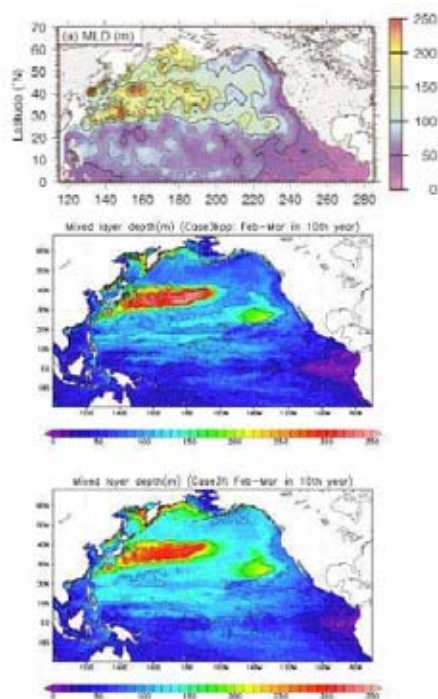


Fig.1

You inspected as the research regarding the disaster weather abnormal weather, concerning the environmental place of the tornado. With the case of the tornado which accompanies the typhoon it made that role is carried out in formation of the environmental place which the tornado is easy to occur due to the correct deviation of sea surface water temperature clear. With the case which accompanies the bomb low pressure, it was suggested that state of the atmosphere of the large overland westerly band has exerted influence on estimate precision. In Fig.2, it is due to the estimate experiment of the bomb low pressure, occurrence potential of the tornado (KHI) the figure of probability is shown. To localized are converted the high probability limits which have been expressed to north Japan before the half-day. As for the gulf stream and near Kuroshio current accompany strong sea surface water temperature slope, from the ocean the mass thermal flux occurs to the atmosphere, is thought that the principal role in air-sea interaction at horse latitude is carried out. With the analysis by Hokkaido University, it was found that focus of the precipitation and the surface wind is supplemented to the gulf stream from satellite observation. Receiving this, us the experiment which gives the sea surface water temperature slope which was observed making use of AFES of horizontal resolution approximately 50km, (standard experiment) with the experiment which gives the sea surface water temperature slope which is smoothed near the gulf stream (smoothing experiment) when it does, with standard experiment the precipitation band which observation in the same way is concentrated on the gulf stream limits was reproduced, but, with smoothing experiment the precipitation band disappeared,

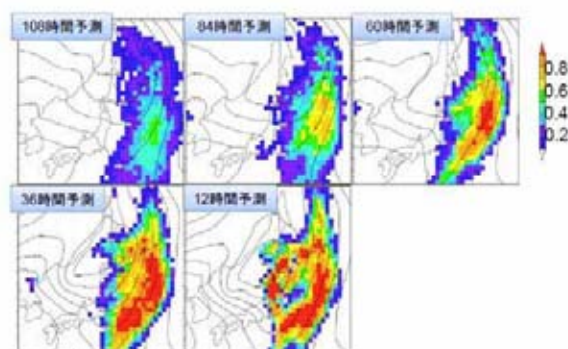


Fig.2

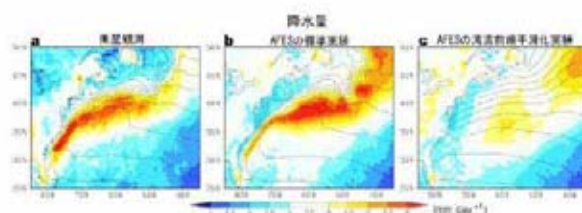


Fig.3

it was suggested (Fig.3) that it is the principal factor to which strong sea surface water temperature slope makes the precipitation concentrate. The result was published to the Nature magazine (Minobe et al. 2008, Nature).

Solid Earth Simulation Research Group performed in this fiscal year; (1) geodynamo simulation, (2) plate-mantle simulation, and (3) earthquake cycle simulation.

Since the development of the geodynamo simulation code had completed by the end of the last year, we have focused on the product runs by making use of 512 nodes (4096 processors) of the Earth Simulator. We succeeded to perform the least viscous geodynamo simulation in which the Ekman number is of the order of 10 to the minus 7th. The convection structure in this low Ekman number regime is different from that observed in the previous simulations with higher Ekman numbers. The flow is organized as a set of thin sheet-like plumes. The sheet plume convection has a strong dynamo effect by which straight magnetic flux tubes are generated. Around the flux tubes, helical coil structure of the electric current is formed (Fig.4).

For the plate-mantle simulation, we have developed a new numerical scheme for nonlinear visco-elastic problems. This scheme enables us to solve large-scale deformation of a visco-elastic fluid on high performance computers. For the validation of this scheme, we have focused on a fluid rope coiling problem. The fluid rope coiling is a nonlinear phenomenon observed in a highly viscous fluid poured onto a horizontal plane (e.g. a honey falling onto toast from a height). We first made a semi-analytical one-dimensional model of this event (1-D model). We then compared this semi-analytical solution with a result of our three-dimensional fluid simulation (3-D model). Our validity test is unique since it provides not only a quantitative comparison (Fig.5), but also a qualitative comparison that incorporates a sharp interface of the material in the Eulerian frame of reference. We expect that this validity test by using the fluid rope coiling problem would become a standard benchmark test of this kind of numerical scheme.

We have developed the basic part of the new code for earthquake cycle simulations with the elastic/viscoelastic heterogeneity in the material distribution. An example of simulation results is showed in Fig.6. In our code, the fault motion is determined by the difference of the fault shear stress and frictional stress obeying a rate- and state-dependent friction law. The spatial discretization of our code is based on the finite element method (FEM) in which the complex material distribution and configuration are easily treated, however, a straightforward application of FEM to this problem causes a numerical error of the stress field on the fault. To exclude this error, we apply a

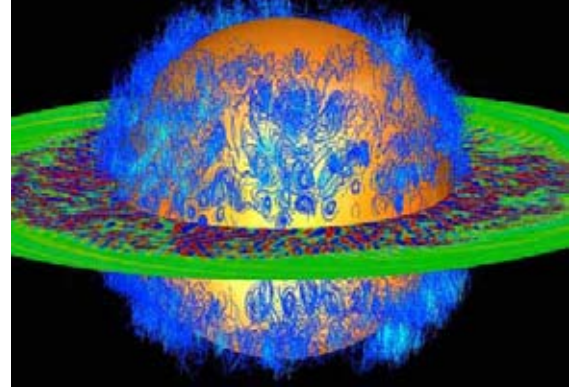


Fig.4 Helical current coils (blue) discovered by high resolution geodynamo simulation with Yin-Yang grid using 4096 processors of the Earth Simulator.

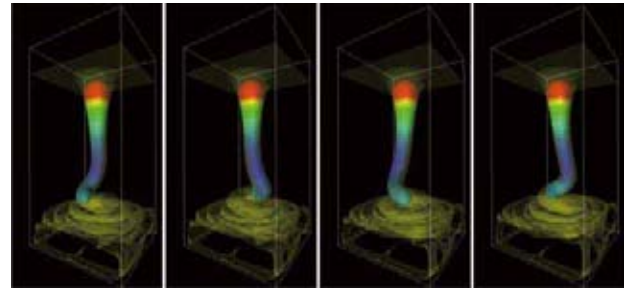


Fig.5 Results of qualitative comparison for fluid rope properties between our simulated 3-D model (semi-transparent yellow isosurface) and semi-analytical 1-D model (colored tube). Good agreement of these two solutions is confirmed by overlaps of isosurface and colored tube.

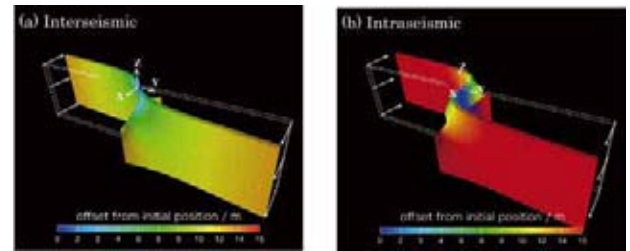


Fig.6 An example of 3-D simulation implemented by our earthquake cycle simulation code. In this case, the fault is modeled as an infinitely long strike slip fault in the direction of X axis.

combination method of boundary integral equation method (BIEM) and FEM. By calculating two stress fields on the same FE grids with different material properties (homogeneous elastic material and heterogeneous one with the homogeneous elastic fault zone), we can exclude numerical errors and extract the fault stress due to the heterogeneity off the fault zone. Therefore, the accurate fault stress is obtained by superposing the differential stress of two FEM calculations and analytic fault stress evaluated by another BIEM calculation. This procedure enables us to simulate earthquake cycles even in a highly complex material.

(2) Advanced Simulation and Technology Development

The Advanced Perception Research Group (APRG) has engaged in research and development for efficient analysis,

faster processing and effective representation on visualization studies for large-scale simulations of geosciences. As our main works for them, two kinds of visualization software, VFIVE and YYView have been continuously developed. VFIVE is an interactive virtual reality (VR) visualization program for CAVE-type VR system, and YYView is a parallel visualization program for large-scale data set.

The basic set of VFIVE sources was released in the fiscal year 2007. It is available to download on the Earth Simulator Center's Web site. Further improvement of VFIVE has been also continued. In that fiscal year, the Region-Of-Interesting (ROI) extraction function was developed and examined, as shown in Fig.7.

In terms of YYView, a GUI tool to edit camera path parameters was newly developed. A screen capture of this program is shown as Fig.8. This function is based on the idea of the fly-through visualization technique in the international collaborative studies with the Computational Visualization Center / University of Texas in the fiscal year 2006.

In addition, APRG has been working on studies for several challenging topics on visualization. In the fiscal year 2007, following three kinds of studies, (1) development of a software-rendering, parallel visualization program, (2) development of a particle visualization program and (3) experiment of photo-realistic visualization of a cloud, were studied.

The program of the item (1) is executable on any parallel computing environment and requires no hardware graphics device. This means that it will improve researcher's working efficiency of data analysis, since it is free of cost involved transferring massive amount of simulation data from storage disks of a supercomputer to user's visualization environment.

For the item (2), particle visualization programs with the point sprite method were developed. The point-sprite method is a kind of the billboard techniques in computer graphics and enables to cut down the number of polygons to model a sphere which represents a particle by replacing its geometry with an



Fig.7 Interactive data analysis of geodynamo simulation with VFIVE in the CAVE's virtual space. It is possible to visualize large-scale data set of the size of 17 GB by ROI extraction function.

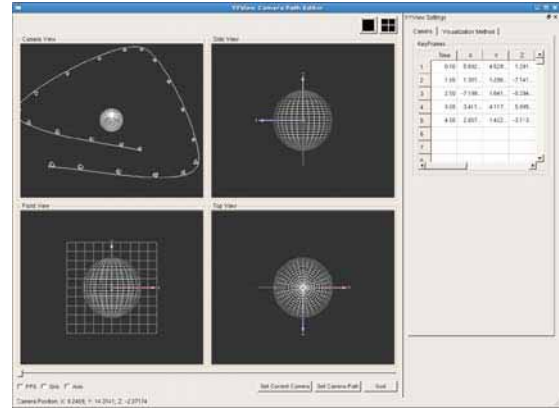


Fig.8 Appearance of a GUI tool to edit camera path parameters.

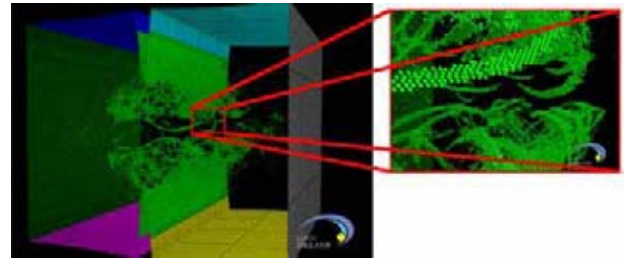


Fig.9 Visualization results of crack tip dislocations by the point-sprite method. This simulation was performed by HSRP of ESC.

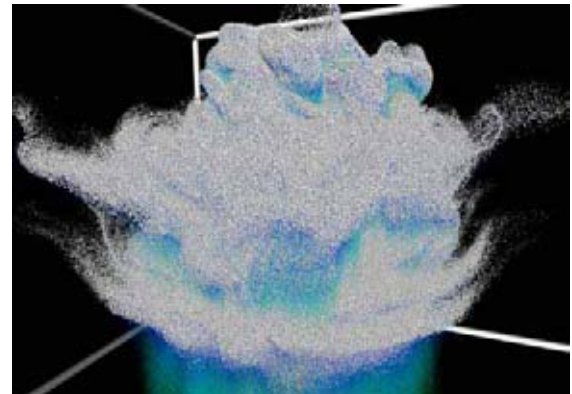


Fig.10 Visualization results of the cloud formation simulation with the super-droplet method by the point-sprite method.

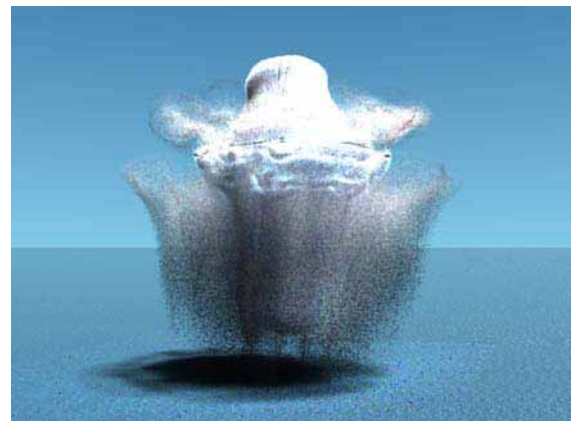


Fig.11 Photo-realistic visualization result of the cloud formation simulation with the super-droplet method (same as in Fig.10). Appearance of a cumulus with vertical growth, soft texture, rainfall and shadow in the cumulus are represented in this figure.

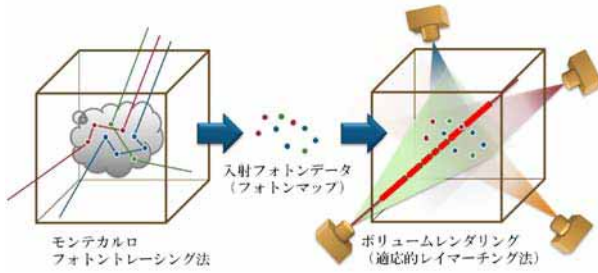


Fig.12 The two-stage approach for photo-realistic visualization of cumulus. The volume photon mapping is applied to connect between the photon tracing simulation and the volume rendering phases.

alternative texture. This approach was applied to the data sets of the simulation of crack tip dislocations (Fig.9) and the cloud formation simulation with super-droplet method (Fig.10), developed by Holistic Simulation Research Program (HSRP).

In terms of (3), two kinds of programs, a photon tracing simulation program based on the Monte Carlo method and a rendering program based on the adaptive ray marching algorithm were developed. An example of the results for the above-mentioned cloud formation simulation is shown in Fig.11. The data of multi-scattered photons by the photon tracing simulation is passed to the rendering program through the volume photon mapping (Fig.12).

Multi-Scale Simulator for the Geoenvironment (MSSG), which is a coupled non-hydrostatic atmosphere-ocean-land global circulation model, has been developed for the purposed of promoting advanced prediction simulation. MSSG is optimized to be run on the Earth Simulator with high computational performance and it is designed to be available with flexibility for different space and time scales. MSSG can simulate phenomena with ultra high small scale such as several meters for horizontal resolution which is required in simulations in urban canyon.

In FY2007, we especially focus on developing model component of urban scale phenomena and cloud physics in meso-scale. In addition, in the purpose of longer simulation, sea ice model was introduced in MSSG in this fiscal year. Simulations

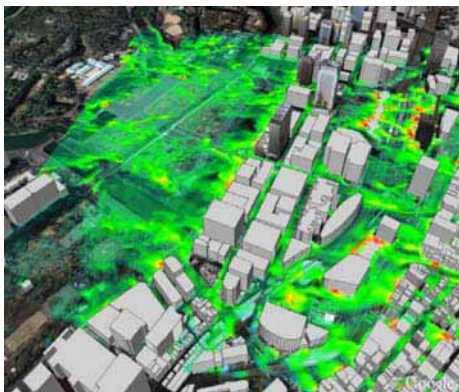


Fig.13 Snapshot of 15 minutes simulation from the initial state by using MSSG coupled the 3D radiation model.



Fig.14 Snapshot of sea ice concentration distribution on 28th February 15 using MSSG coupled to the introduced sea ice model.

for non-steady states in urban canyon layers were promoted by MSSG coupled by the three radiation process model. Snapshot of the simulation is presents in Fig.13. It aimed to understand heat radiation mechanism in urban canyon area and three dimensional radiation process model was developed. It is indispensable for simulation of heat island phenomena influenced from thermal storage process among walls on building and road. Heat tends to be stored in lower level in city canopy layer and its tendency was appeared on walls toward the all direction and eddied due to convection was tend to be trapped in the city canopy layer.

The collision process is considered as quite important process to represent real sea ice distribution, because radiation process in the atmosphere is influenced by the distribution and mixed layer in the ocean as well. Especially, ultra high resolution simulation is required to understand the impact to Japanese climate system by intermediate water formation in the Okhotsk Sea. Preliminary experiments were promoted in the current year to represent sea ice distribution by the new introduced model with MSSG-O. Snapshot of the simulation is comparable to the observational data. Furthermore, sea ice collision effects are remarkable in the front of sea ice distribution and made improved distribution of sea ice with low concentration as shown in Fig.14.

(3) Holistic Simulation Research

The Holistic Simulation Research Program worked on the development of a new simulation model capable of handling diverse interactions between hierarchical layers, and made progress in research aimed at applying this model to plasma, cloud, solid and other layered phenomena.

The Holistic Algorithm Research Group worked on the following research topics: (a) Using "Super-Droplet Method", a novel particle-based simulation model of cloud microphysics, a very high-resolution three-dimensional simulation of shallow maritime cumulus formation was performed (Fig. 15). (b) Using

a micro-macro interlocked (MMI) simulation for gas detonation, effects of non-thermal velocity distribution on the chemical reactions was analyzed (Fig.16). (c) An interlocked plasma simulation was developed and applied for the collisionless shock problem in order to investigate the shock dissipation process and the diffusive shock acceleration process (Fig. 17). (d) A MMI simulation scheme for an oscillatory reaction-diffusion system was developed in which micro simulation regions are activated or deactivated dynamically (Fig. 18).

The Applied Simulation Research Group worked on the following research topics: (a) A platform for massively parallel simulation for molecular dynamics was developed to investigate friction and fraction, which are typical multi-scale phenomena (Fig. 19). (b) Using a MMI simulation, the effect of microscopic instability on macroscopic structure formation in the process of quiet auroral arc formation was studied (Fig.20).

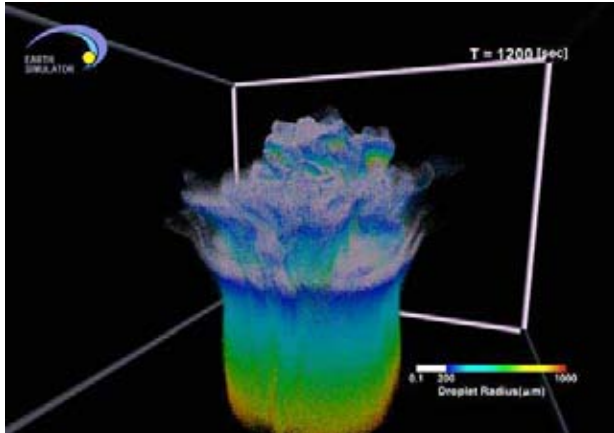


Fig.15 Very high-resolution 3-D Simulation of shallow maritime cumulus formation and precipitation using the Super-Droplet Method.

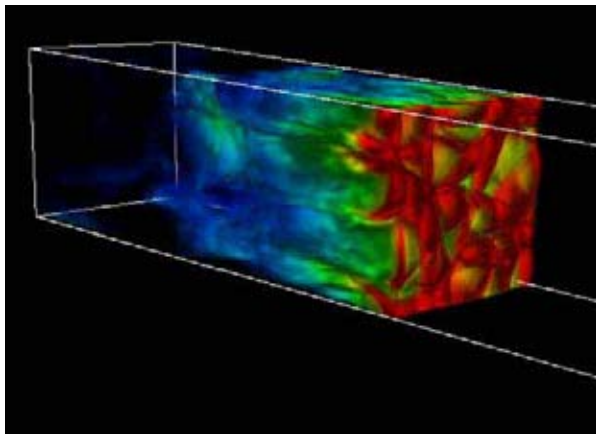


Fig.16 Pressure distribution in a MMI simulation for gas detonation.

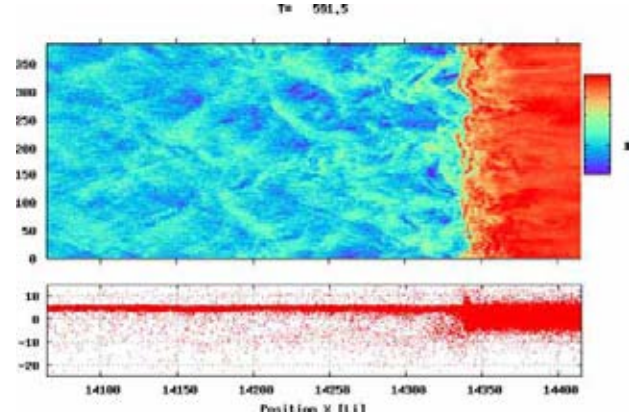


Fig.17 Density contour plot (upper panel), and phase-space plot in X - V_x . X :shock normal direction.

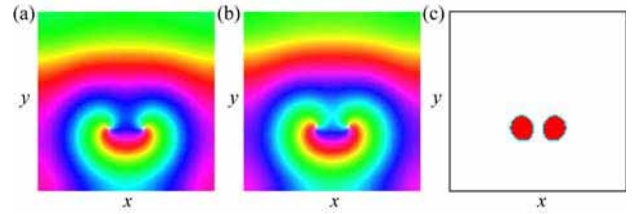


Fig.18 Comparison between (a) direct simulation and (b) MMI simulation of attractive interaction of two-phase singularities. Plot (c) indicates regions where direct simulation is activated.

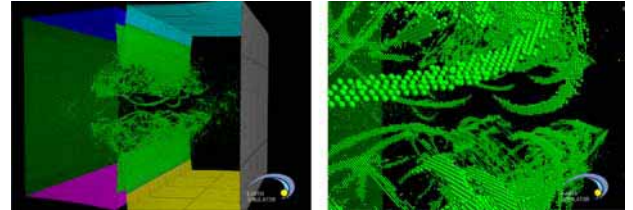


Fig.19 Molecular dynamics simulation of fracture in Lennard-Jones material. Only atoms of larger potential energy are drawn to show dislocations.

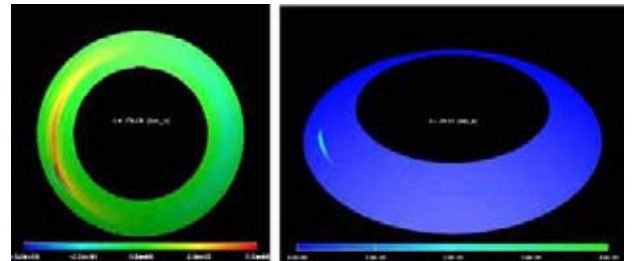


Fig.20 Distribution of the field aligned current density at ionosphere height (left) and distribution of the oxygen green line emission intensity at 110-130 km altitude (right).

1.3 Various research and development activities

1.3.1 Promotion of ingenious and pioneering research and development

The “Research and Development Promotion Award”, which was implemented in 2004 in order to sprout new, original research and development projects, as of 2007 incorporated a total of 16 such projects. These included: 4 projects from the “Inter-sectional (inter-center) Research and Development Promotion Award”, which develops the foundations for encouraging research and development cooperation both internally across JAMSTEC's various sections, and externally with industrial, academic and government partner institutions. 1 project from the “Cutting-Edge Measuring Technology Research and Development Promotion Award” that aims to promote the technological development of, among others, sensors, measuring equipment, observation tools and experimentation instruments to be utilised in the development of marine science technology hereafter. 10 projects from the “Pioneering Research and Development Promotion Award”, which focuses on finding and cultivating the important seeds recognised as having the potential to become the foundations for future marine science research and development, and therefore judged suitable for incorporation into the preparation stage of the next mid-term plan.

In 2007 a conference was held to present the results of the above projects. An evaluation of these results was also undertaken by the “Research and Development Award” Committee chaired by Dr Suehiro, Director of research and development, in order to determine which of these projects should be continued into 2008.

Concerning one of the main medium and long term goals of JAMSTEC, the “Earth System Science Award” which aims at the “integrated understanding of Earth Life Systems” and using System Science approaches that go beyond existing frameworks and procedures, the recruitment of projects that incorporate the concept of a “Virtual Laboratory” not restricted by existing organisations was undertaken. 1 project from among those that applied was subsequently adopted. In addition, the recruitment of projects to be started from 2008 as part of the 'Pioneering Research and Development Award' was implemented.

Table 1 Research and Development Promotion Awards

Name	Inter-sectional Research and Development Promotion Award	Cutting-edge Measuring Technology Development Award	Pioneering Research and Development Promotion Award	Earth System Science Award
Target	Inter-sectional (inter-center) research and development projects of various sectors within the JAMSTEC and research and development projects based on collaboration with external organizations in industry, academia and government Conditioned on all or one of the items below: (1) Inter-sectional research and development projects conducted by various centers within JAMSTEC based on the creativity of JAMSTEC researchers and engineers (2) Research and development projects aiming at synergistic effects of multiple centers and successes in collaboration with external organizations in industry, academia and government	Projects aiming at promoting the “Development of technologies necessary for future development of marine science and technology including sensors, measuring instruments, observation devices, experimental instruments and others”, establishing a global standard for developing sensors capable of measuring phenomena that were not measurable up to now and developing sensors and the like that significantly reduce price, cost and time required in measuring various phenomena	Projects aiming at promoting seeds important for the infrastructural research and development as a prelude to be incorporated into research and development projects in the next mid-term plan and promoting original ideas young researchers have concerning marine science and technology so that they are grown as effective researchers.	Projects aiming at the “Comprehensive understanding of earth-life interactive system” as a target of a mid- to long-term research and development of JAMSTEC and promoting “Earth system science research award” using the system science beyond the existing limit and procedure
Those making the proposal	Those eligible to make the proposal are mainly staff members at the rank of group leader or lower. Director Generals of Research Centers, Program Directors and others cooperate actively when projects are proposed as well as additionally providing full-scale backup in guiding those making the proposal, allocating the project expenses for next year and beyond and participating in the research when proceeding the programs which have been adopted.	All staff members	All staff members at the rank of sub-leader or lower	All staff members
Scale and term of research expenditure	Since the expenditure for this award is characteristically related to the initial stage of total project expenditure, the usual expenditure after launching the project is appropriated for each center based on the progress of the project made. Three years is the maximum term of the award. Upper limit of the expenditure for one project is; First year; around ¥50 million Second year; ¥50 million Third year; ¥10 million	Two years is the maximum term. Upper limit of the expenditure First year; ¥30 million Second year; ¥10 million	Three years is the maximum term. Upper limit of the expenditure per year; ¥5 million	Total expenditure is within ¥100 million, in which the total personnel expenditure is limited to ¥30 million.
Screening and adoption	The Planning Director of the Planning Department appraises and determines the cost allocated to research projects. A committee is formed to screen and select projects focusing on the following criteria; (1) Consistency with the purpose of each award (2) Clear statement of goals achievable within a time frame (3) Foresight, originality and compatibility of ideas with the philosophy on which JAMSTEC is founded (4) Appropriateness of project team organization (5) Appropriateness of project expenditure required (including its specific breakdown) (6) Operability of schedule (7) Performance that proves the capability of the project team (8) Trends at home and abroad After examining documents as needed, a conference is held to present project proposals. Proposals presented are then examined by the Committee and the President decides which proposed projects are adopted based on the results examined by the Committee.			
Committee (name)	Research and Development Promotion Award Committee			
Composition	Dr. Suehiro, the Chairman, the Vice Chairman, Directors and a few committee members selected by the Chairman (Directors, Operating Officers and researchers and engineers of JAMSTEC active in the front lines) form the “Research and Development Promotion Award Committee”, which carefully screens the projects based on the proposed documents and their presentation.			
Secretariat (General Affairs)	The Committee is operated by the Planning Section of the Planning Department			
Report	The research practitioners have to submit a report on research completion to the President and the Chairman of each Committee within three months after completing their research. The research practitioners have to orally report their findings to the Committee on the date set by the Committee during and after completion of the research.			

Table 2 Research and Development Promotion Award in FY 2007: List of Themes

Number	Name of theme	Class of award	Name of research representative	Affiliation	Position	Participating researchers Research collaborators	Expenditure (unit: ¥1000)				
							Total project expense	FY 2004	FY 2005	FY 2006	FY 2007
1	Interaction of mantle and life in the earth history: Proof of [Ultranaftics Hydrothermalism-Hydrogen-HyperSLIME] linkage (UltraH3-linkage)	Inter-sectional Research and Development Promotion Award	Ken Takai	XBR	PD	IFREE: Hidenori Kumagai, Katsuhiko Suzuki XBR: Fumio Inagaki XBR: Yohey Suzuki, Hisako Hirayama, Takuro Nunoura, Shinji Tsuchida IFREE: Takeshi Hanyu, Keiko Sato University of Tokyo: Kentaro Nakamura, Kensaku Tamaki, Toshitaka Gamo, Yu-ji Sano, Kyoko Okino AIST: Yoshinori Takano, Kiyoyuki Kishimoto Hokkaido University: Urumu Tsunogai Kyoto University: Kei Okamura CRIEPI: Kiminori Shitashima Kanazawa University: Tomoaki Morishita Senshu University: Hiroshi Sato Toyama University: Arata Yoshihara	145,301	75,500	34,141	6,600	29,000
2	Development of a system for simultaneous surveys on both marine snow and plankton in mid- to deep-sea areas with concurrent measurement of environmental factors	Inter-sectional Research and Development Promotion Award	Dhugal Lindsay	XBR	Researcher	XBR: Minoru Kitamura MARITEC: Hiroshi Yoshida, Tetsu Tsukioka, Tadahiro Hyakudome, Shojiro Ishibashi, Jun-ichiro Tahara, Takuya Shimura XBR: Yasuo Furushima, Shinji Tsuchida IORGC: Nobuyuki Shikama, MBARI: Bruce Robison, Duane Edgington University of Tokyo: Jun Nishikawa JSF: Hikaru Okuno Misaki Marine Biological Station, University of Tokyo: Koji Akasaka	141,594	-	77,510	38,160	25,924
3	Immune factors concerning recognition of microbes and the defense system in marine mammals	Pioneering Research and Development Promotion Award	Kazue Ohishi	XBR	Researcher	XBR: Kiyotaka Takishita, Takao Yoshida XBR: Masaru Kawado Hakkeijima Sea Paradise: Hiroshi Tokutake Kamogawa Sea World: Etsuko Katsumata Okinawa Chura Aquarium: Kei-ichi Ueda Kanazawa Zoo: Hirotaka Nakamura	21,840	-	9,300	7,740	4,800
3	Development of precise Mg and Ca isotopic analysis technique for clarifying the oceanic-biological cycles	Pioneering Research and Development Promotion Award	Masaharu Tanimizu	Kochi Institute for Core Sample Research	Researcher	IFREE: Takashi Toyofuku	15,104	-	5,436	7,668	2,000
3	Biological responses of marine calcareous plankton to environmental changes and its applications in paleoceanography	Pioneering Research and Development Promotion Award	Katsunori Kimoto	IORGC	Researcher	IFREE: Masashi Tsuchiya	21,120	-	4,620	8,100	8,400
5	Google Earth as geoscience data browser project	Pioneering Research and Development Promotion Award	Yasuko Yamagishi	IFREE	Researcher	IFREE: Seiji Tsuboi, Katsuhiko Suzuki Kochi Institute for Core Sample Research: Hajimu Tamura Kochi Institute for Core Sample Research: Masaharu Tanimizu	5,000	-	-	-	5,000
5	Environmental changes during the Cretaceous Oceanic Anoxic Event based on sedimentary Pb isotopic record	Pioneering Research and Development Promotion Award	Junichiro Kuroda	IFREE	Researcher		3,900	-	-	-	3,900
5	Integration of environmental engineering with microbiology-cultivation of uncultured fastidious marine subsurface microorganisms using flow-through type bioreactor-	Pioneering Research and Development Promotion Award	Hirofumi Imachi	XBR	Researcher		5,000	-	-	-	5,000
5	Introducing "third molecular biology" into the study of deep-sea ecosystems: towards a molecular understanding of inter-species interactions mediated by glycans	Pioneering Research and Development Promotion Award	Satoshi Nakagawa	XBR	Researcher	XBR: Shigeru Shimamura, Kazue Oh-ishi, Takao Yoshida, Hiromi Watanabe, Hiroko Makita, Yoshihiro Takagi, Masahiro Yamamoto, Tomo-o Watsuji, Fumio Inagaki, Ken Takai Nagoya City University: Ko-ichi Kato LSHTM: Brendan Wren	5,000	-	-	-	5,000
5	Research on the autonomous working function of manipulators for an unmanned underwater vehicle	Pioneering Research and Development Promotion Award	Shojiro Ishibashi	MARITEC	Researcher		5,000	-	-	-	5,000
5	Search and functional evaluation of genes of unknown microorganisms by substrate-induced gene expression screening in subsurface biosphere	Pioneering Research and Development Promotion Award	Yuki Morono	Kochi Institute for Core Sample Research	Researcher	Kochi Institute for Core Sample Research: Fumio Inagaki, Nobuaki Masui AIST: Taku Uchiyama	5,000	-	-	-	5,000
5	Research and development of a power generation equipment based on fluid energy	Pioneering Research and Development Promotion Award (received the Research Incentive Award of the Committee Chairman)	Tadahiro Hyakudome	MARITEC	Researcher	MARITEC: Hiroshi Yoshida, Kazukage Ito	1,000	-	-	-	1,000

5	Development of full-depth ocean data assimilation system and its application to ocean general circulation study	Inter-sectional Research and Development Promotion Award	Takeshi Kawano	IORGC	SL	FRCGC: Toshiyuki Awaji, Mochisane Sugiura, Shuhei Masuda, Takahiro Toyoda, Takuji Sasaki IORGC: Yoshimi Kawai, Katsuo Katsumata, Shinya Ayase, Tomomasa Doi Mutsu Institute of Oceanography: Shu-ichi Watanabe DIAG: Yasunori Hanafusa, Takanori Hatakeyama, Hiromichi Igarashi IORGC: Masao Fukasawa	12,000	--	--	-	12,000
5	Integrated survey on the function of the subsurface life in the methane hydrate-bearing region off the Shimokita Peninsula	Inter-sectional Research and Development Promotion Award	Fumio Inagaki	Kochi Institute for Core Sample Research	GL	Kochi Institute for Core Sample Research: Yuki Morono, Noriaki Masui XBR: Ken Takai, Toru Kobayashi IFREE: Nanako Ogawa, Yoshinori Takano, Naohiko Ohkouchi MWJ: Takeshi Terada, Katsuyuki Uematsu XBR: Hiroyuki Imachi, University of Tokyo: Ryo Matsumoto, Lika Takeuchi, Katsunori Yanagawa, Yuji Sano, Naoto Takahata Tokyo Institute of Technology: Manabu Nishizawa AIST: Hideyoshi Yoshioka Kitami Institute of Technology: Hitoshi Tomaru University of Bremen: Julius S. Lipp, Kai-Uwe Hinrichs	50,000	-	-	-	50,000
5	Fluid-controlled high-speed shear testing apparatus for comprehensive understanding of fault slip behavior	Cutting-edge Measuring Technology Development Promotion Award	Wataru Tanigawa	Kochi Institute for Core Sample Research	Researcher	Kochi Institute for Core Sample Research: Tameto Hayashi, Takehiro Hirose Kochi Institute for Core Sample Research: Koji Ishikawa Osaka University: Tetsuo Hirono Hiroshima University: Toshihiko Shimamoto	27,500	-	-	-	27,500
6	"Precambrian Ecosystem Laboratory"	Earth system science Award	Ken Takai	XBR	PD	IFREE: Hidenori Kumagai, Katsuhiko Suzuki Precambrian Ecosystem Laboratory: Kosei Yamaguchi XBR: Jun-ichi Miyazaki, Masahiro Yamamoto IFREE: Kentaro Nakamura, Takeshi Hanyu, Yuka Hirahara, Ryoko Senda XBR: Satoshi Nakagawa, Hisako Hirayama, Takuro Nunoura, Masayuki Miyazaki AIST: Yohey Suzuki, Kiyoyuki Kishimoto, Masato Joshima University of Tokyo: Toshitaka Gamo, Shinsuke Kawagucci, Noriaki Tsunomori, Kensaku Tamaki, Kyoko Okino Ryukyu University: Tomohiro Toki Kyushu University: Jun-ichiro Ishibashi Okayama University: Hitoshi Chiba Hokkaido University: Urumu Tsunogai Tokyo Institute of Technology: Shigenori Maruyama, So-ichi Ohmori, Yu-ichiro Ueno Kanazawa University: Tomoaki Morishita Senshu University: Hiroshi Sato Kohoku Junior College: Takashi Sawaguchi University of Southern California: K.H.Nealson Woods Hole Oceanographic Institution: Jian Lin University of Bremen: Wolfgang Bach	25,000	-	-	-	25,000

1.3.2 Promotion of collaborative research and research partnership

① Collaborative research

A total of 60 collaborative research projects were conducted in FY 2007, of which 19 projects were new. Their breakdown is given in the following table.

Organization	Number of projects*
Universities and inter-university research institutions	22 (6)
National, local government and independent administrative institutions	23 (9)
Private enterprises and foundations	18 (3)
Foreign institutions	2 (1)

* The numbers in parentheses indicate the number of new projects adopted in FY 2007. The numbers in breakdown are the number of partners. Since some projects were conducted with more than one partner, the total number differs from the numbers of contract.

(a) To promote exchanges concerning JAMSTEC's research and development, efforts were continued to promote collaboration with universities and research institutions and four new agreements were realized with institutions.

(b) To make smoother collaborative research based on agreement with institutions, rules for approval authorities were modified to have the system of making contract agreement easier than previous processes in conventional collaborative research (modified on March 25, 2008 and enforced on April, 1, 2008)

② International Activities

(a) Research activities of IARC and IPRC

Research on observations of the global environment and forecasts of global environmental changes was continued at both the International Arctic Research Center (IARC) and the International Pacific Research Center (IPRC)

(b) Agreements

To cooperate with research institutions abroad, JAMSTEC concluded agreements with 19 institutions as of the end of FY 2007. In addition to new agreement with the Korean Institute of Geology, Mining and Materials (KIGAM), JAMSTEC renewed agreements with Texas A&M University (TAMU) in US, the French Research Institute of Exploiting the Sea (IFREMER) in France and the Monterey Bay Aquarium Research Institute (MBARI) in US. We are also currently working to revise agreements with the Pacific Marine Environmental Laboratory in the National Oceanic and Atmospheric Administration (NOAA/PMEL) in US, the Woods Hall Oceanographic Institution (WHOI) in US and the National Oceanography Center, Southampton (NOCS) in UK.

(c) Visits of foreign VIPs and international activities

The Duke of York, Royal Family visited on May 30, 2007 the Yokohama Institute of Earth Sciences to tour the Earth Simulator and other facilities, commune with researchers from UK and then move to the Yokosuka Headquarters, where he

toured the deep sea cruising AUV, "URASHIMA", the manned research submersible, "SHINKAI 6500" and others. Mr. Wolform, the Chief of the International Tribunal for the Sea visited on November 19, 2007 the Yokosuka Headquarters to exchange opinions concerning "Handling of marine genetic resources in high sea under enforcement of the international treaty for the Law of Sea and tour facilities focusing on the Extremobiosphere Research Center and others.

Full session of the fourth meeting of the Group on Earth Observations (intergovernmental meeting for earth observations) and summit conference by cabinet members were held on November 28-30, 2007 in Cape Town, South African Republic. Twenty five representatives from Japan including Mr. Tokai, Minister of Education, Culture, Sports, Science and Technology and two representatives from JAMSTEC (Institute of Observational Research for Global Change) participated in the full session and at the same time we exhibited the results of "Construction of Radar Network for Observation of Ocean and Continent" (plan of promoting global observational system) performed by JAMSTEC.

The "Promotion Committee for Collaboration with Intergovernmental Oceanographic Commission (IOC)" was established within JAMSTEC in January, 2008 in order to enhance the system for promoting our research programs related to the international research projects of IOC.

Mr. Bernal, the Secretary General of IOC in UNESCO visited the Yokosuka Headquarters on February 26, 2008 and toured our facilities.

③ Agreements with institutions newly concluded in FY 2007

* National Institute of Advanced Industrial Science and Technology (AIST) (concluded on March 7, 2008 and entitled with "Agreement on Comprehensive Collaboration for Promoting Cooperation between JAMSTEC and AIST)

* National Museum of Nature and Science and Kanagawa Prefectural Museum of Natural History (concluded on November 15, 2007 as a three party agreement and entitled with "Agreement on Collaboration of Operating Database of Marine Organisms"

* Kobe University and University of Hyogo (concluded on August 6, 2007 and entitled with Agreement on Comprehensive Collaboration in Educational Research at Kobe University, University of Hyogo and JAMSTEC)

* Japan Oil, Gas and Metals National Corporation (concluded on July 23, 2007 as a master agreement and entitled with Agreement on Comprehensive Collaboration of Research and Exploration in the Field of Marine Resources"

(1)The International Arctic Research Center (IARC)

The International Arctic Research Center at the University of Alaska Fairbanks is an international focal point for (1) synthesis of our understanding of the Arctic System and (2) the application of this understanding to prediction of the evolution of the Arctic system over the next century. Our over-arching goal is to reduce the uncertainty in predictions of Arctic change. In order to do so, we must understand ongoing changes. Understanding, in turn, requires attribution in terms of characterizing and quantifying linkages among system components. IARC's strategy for synthesizing our understanding and predictive capabilities is to entrain the international Arctic research community into activities that are essential for scientific progress and that are not amenable to support through conventional funding channels. We have strived to conduct process studies and collect field measurements that may provide the understanding needed to develop and validate models. Examples include quantifying the variability in distribution, age structure and thickness of perennial sea ice. This understanding is central to the development of coupled models of atmospheric dynamics, oceanic circulation and sea ice degradation and export. The physical and biological controls of carbon fluxes are at the core of global change, yet quantifying methane and CO₂ fluxes in the Arctic and assessing their feedbacks are among the greatest challenges facing the Arctic research community. Documenting physical changes in the climate will contribute nothing to our understanding if we do not synthesize those observations into higher-level analyses of ecosystem responses. All of these activities are key components of the Arctic System and will provide the tools and understanding needed to predict the system level responses to a changing climate.

We are pleased to continue our ongoing collaborations with our colleagues at the Japan Agency for Marine-Earth Science and Technology and look forward to increased scientific exchanges and cooperation. The scientific questions currently facing our nations may be more efficiently and appropriately addressed through collaboration and shared understanding. We believe the results contained within this report will contribute to our collective knowledge of the arctic system. Our activities have been numerous and varied. A summary of some achievements follows.

We improved the Coupled Ice-ocean Model as needed in development of the Ice-Ocean-Ecosystem Model, implementing lateral melting. We also introduced as a new variable the bulk heat transfer coefficient, Kb, depending on wind speed. We

found that the Dipole Anomaly (DA) is more important than AO dynamically in driving sea ice out of Arctic Ocean. Recent sea ice minimum in summers of 2003, 2005 and 2007 in the Western Arctic can be explained by the Arctic DA, which produces meridional (southerly) wind anomaly. The minimum sea ice (or maximum open water) scenario in the Western Arctic (i.e., Beaufort Sea and Alaska coast) was driven by the combined climate state of +DA and -AO.

We also focused on the development of a more realistic formulation of ice-ocean coupling that includes tides and has sea ice floating in the ocean rather than 'levitated' or separated from the ocean as is the norm in coupled global climate models. Initial results from this effort have focused a barotropic ice ocean model with a bulk boundary layer with sea ice 'embedded' in the oceanic boundary layer. With this formulation, in the absence of ice interaction with tidal forcing alone there is no artificial shear between the ice the boundary layer and the deep ocean and no unphysical inertial resonance. In contrast when sea ice is levitated and coupled to a barotropic ocean there is an artificial clockwise rotary resonance of the sea ice even in the absence of ice mechanics. Initial results with preliminary results show that ice-tide interaction is significant. With improved model physics, we plan to investigate the tidal role in shaping Arctic climate.

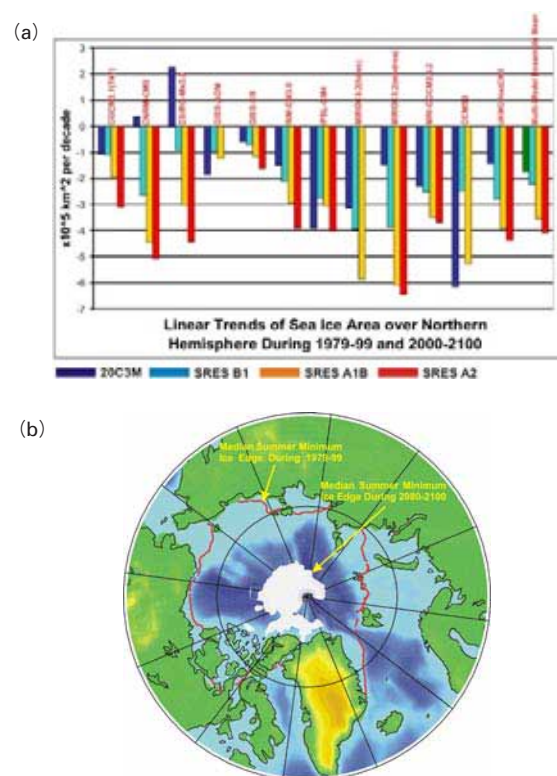


Figure1. (a) The simulated and projected Arctic sea ice area declining rates in the 20th century and under various global warming scenarios by the IPCC AR4 climate models; and (b) the multi-model composite of median sea ice coverage (Zhang 2008).

Research to develop a 4Dvar data assimilation model has led to a new version of the *Semi Implicit Ocean Model*. New features of the model are: a) implicit formulation of the diffusive adjustment; b) orthogonal curvilinear coordinates c) hybrid (z and σ) vertical grid; d) a tangent linear model obtained by direct differentiation of the forward model code; e) an adjoint code of the model built analytically by transposing the operator of the tangent linear model.

As a continuing work on the simulated Arctic sea ice changes by the IPCC AR4 models, we have examined climate sensitivity of Arctic sea ice coverage to the global warming forcing to improve understanding of their credibility and uncertainties (Figure 1). In their previous study serving as a contribution to the IPCC AR4, we showed that the changes in the Arctic sea ice coverage to global warming forcing exhibit a large diversity across climate models and across climate model ensemble members. This constitutes a major source of uncertainty in the projection of future Arctic climate change.

Reanalyses represent important sources of data for climate analyses. They are based on weather forecast models and so work best when they are constrained by assimilated observational data. In areas of low data availability the level of model constraint is correspondingly low and the accuracy of the reanalysis can be of concern. A large comparison effort was run in which NCEP/NCAR reanalysis data were contrasted with observational data taken from floating ice islands operated by the US and Russia over the last 50 years. Results from this effort showed that, on average, many of the parameters do not suffer from excessive error, although there were discrepancies,

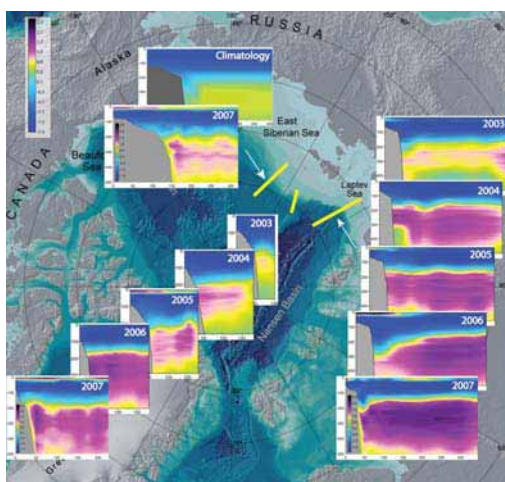


Figure2 Vertical cross-sections of water temperature ($^{\circ}\text{C}$) from the Siberian slope (see three series of cascaded plots related to three locations shown by yellow lines on the map). These observations provide evidence of unprecedented warming of the Arctic Ocean

for example, 2m air temperature was $>1^{\circ}\text{C}$ higher than observed in the summer.

Our observations of currents and temperature of the Arctic Ocean in previous years showed that the exceptional warming that entered the Eurasian Basin in 1999 progressed from Fram Strait along the Barents and Laptev slopes. This year CTD cross-section carried out in the East Siberian Sea show that this warming finds its way towards the Alaskan backyard. The magnitude of this warming is unprecedented with no analogy in the history of regional instrumental observations. The unique strength and spatial distribution of this warm surface anomaly suggests the important role of oceanic heat in shaping this summer's substantially reduced ice cover of the Arctic Ocean. The intrusion of warm Atlantic water, combined with the on-going reduction of the sea-ice cover, will have major impacts on the unique Arctic fauna and ecosystems (Figure 2)

Research was conducted to estimate the continuous monitoring of soil respiration (e.g., CO_2 efflux) using automatic chamber system that was equipped with a control system, a compressor, and six chambers (50 cm diameter, 30 cm high) set in sphagnum moss, feather moss, lichen, and tussock in black spruce forest soils, interior Alaska during growing season of 2007. The average daily soil respirations were 0.092 ± 0.024 (standard deviation, CV 26%), 0.058 ± 0.011 (19%), 0.132 ± 0.097 (73%), and $0.117 \pm 0.038 \text{ mgCO}_2/\text{m}^2/\text{s}$ (32%) in lichens, sphagnum moss, tussock and feather moss on black spruce forest soils with light chamber made by transparent material, and 0.255 ± 0.009 (35%) and $0.061 \pm 0.016 \text{ mgCO}_2/\text{m}^2/\text{s}$ in tussock and sphagnum moss with dark chamber wrapped with aluminum foil for the effect of ground vegetation's respiration. The averaged regional soil respiration rate is $0.19 \pm 0.18 \text{ kgC}/\text{m}^2/(\text{growing period})$ in black spruce forest soils, interior Alaska. The winter soil respiration was $49 \pm 13 \text{ gC}/\text{m}^2/(\text{winter season})$, corresponding to $26 \pm 7\%$ of the annual CO_2 emitted from black spruce forest soils, interior Alaska.

(2) IPRC Research Report on JII Activities during FY2007

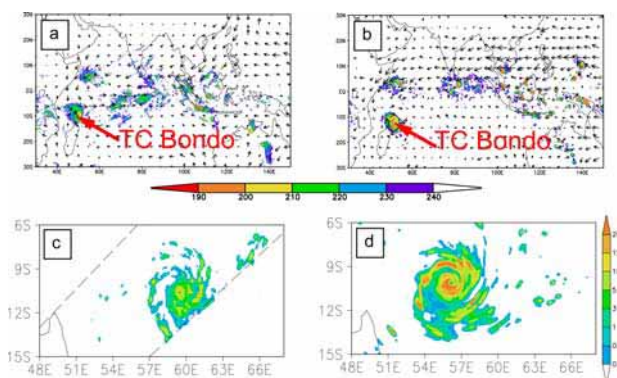
IPRC conducts research in collaboration with JAMSTEC under the "JAMSTEC-IPRC Initiative (JII)" which currently includes efforts in seven different research themes.

JII Theme 1 Model development, diagnosis, and applications

Theme 1 research aims to evaluate high-resolution atmospheric model performance, to improve representations of physical processes in regional and global fine-resolution models, to advance understanding of complex scale interactions in the cli-

mate system and so improve parameterization schemes for coarser resolution climate models.

The first global cloud-resolving model (CRM) the Nonhydrostatic ICosahedral Atmospheric Model (NICAM) has been developed at JAMSTEC. NICAM has been run with horizontal resolutions of a few km over the globe and so can simultaneously model cloud clusters, organized mesoscale convective systems, and the associated large-scale circulations, such as Madden-Julian Oscillation (MJO). In one integration from realistic initial conditions NICAM successfully simulated a real MJO event that occurred over the next month. NICAM reproduced not only the large-scale organized cloud systems in the MJO, but also the lifecycles of multiscale cloud clusters. Analysis conducted at IPRC has shown that in this integration the model also successfully simulated the lifecycles of two tropical cyclones (TCs) that occurred over the Indian Ocean. The success results from the realistic simulations of not only the large-scale circulation, such as the MJO and the cross-equatorial flow, but also the embedded mesoscale convective systems, such as vortical hot towers.



(a) Equivalent black body temperature (K) and 850-hPa winds from observations and (b) outgoing long-wave flux (W per square m) and 850-hPa winds from NICAM simulation at 1200 UTC 21 December 2006. (c) Observed (TRMM) and (d) simulated surface rain rate (mm per hour).

JII Theme 2 Atmospheric composition

Theme 2 research is aimed at understanding of atmospheric aerosol/cloud/chemistry/physics interactions and their climate effects, with a focus on the Asia-Pacific region.

Work has initially focussed on modeling aerosol cloud interactions. A double moments scheme for cloud microphysics properties was implemented in the IPRC regional atmospheric model and is now being extensively tested in simulations of the tropical Eastern Pacific Ocean region.

JII Theme 3 Climate variability and predictability

The goal of this theme is to improve the description, understanding, and simulation of oceanic, atmospheric, and coupled

processes, modes of climate variability, and seasonal predictability.

Major progress in extratropical ocean-atmosphere interaction has been made through the following studies, each showing that the atmospheric effects of oceanic fronts are much deeper than previously recognized. (1) Satellite analysis shows that the subtropical front of the Northwest Pacific anchors a deep convective rainband during April-May, leaving a distinct surface signature with positive wind curls. (2) Analysis of variability in high-frequency eddy temperature flux suggests it likely that SST anomalies along the Gulf Stream and Kuroshio/Oyashio produce the atmospheric anomalies. (3) A series of idealized AFES experiments show a pronounced influence of mid-latitude ocean fronts on the storm tracks, the surface westerlies and the annular mode. (4) A synthesis of observational analysis and AFES experiments reveals Gulf Stream influence that penetrates into the upper troposphere.

JII Theme 4: Ecosystem dynamics

JII Theme 4 aims to improve understanding of the impact of climate variability and climate change on marine and terrestrial ecosystems. The particular focus is the primary production of the marine ecosystem in the Indo-Pacific Oceans and their marginal seas. Understanding and quantifying the variability in ocean primary production is important because of its impact on the uptake of carbon dioxide by the ocean, and potential feedbacks with the climate system.

One issue being studied is the maintenance of the Arabian Sea oxygen minimum zone. Analysis has begun on an integration of the OFES global ocean model including CFC-11 as a tracer. The modeled salinity and CFC-11 have been compared with observations. The model salinity near the salinity maximum in the Arabian Sea decreases to unrealistic values on multi-decadal timescale, and the model CFC-11 concentration is lower than the observed values. These results suggest that the outflow of the high salinity water from the Red Sea is weaker in the model than in the real world.

JII Theme 5 Hydrological cycle and monsoons

Research in Theme 5 has the goal of improving understanding of the variability of the monsoon circulation and associated hydrological cycle, including the role of coupled atmosphere-land processes and the interaction between tropical cyclones and monsoon circulations.

Defining the strength of the East Asian summer monsoon (EASM) is controversial. After examination of 25 existing EASM circulation indices, a new unified index defining the strength of the EASM has been proposed, which represents the

principal component of the leading mode of the EASM interannual variability. The proposed index highlights the significance of the Meiyu/Baiu/Changma rainfall variability.

The tropical intraseasonal variability (TISV) in simulations with the MRI-TL959L60 AGCM has been documented. Specifically, the mean state, power spectra, propagation features, leading EOF modes, vertical structure, and seasonality associated with the TISV have been characterized.

JII Theme 6 Paleoclimate dynamics

Theme 6 research focuses on the mechanisms of glacial terminations and inceptions, the origin of millennial-scale variability and the interaction between glacial ice sheets and the climate system.

The period from 18000-14600 years before present, was characterized by major reorganizations of the global ocean circulation. Recent analyses of sediment cores from the northern North Pacific by colleagues at IORGC further suggest that during this period the North Pacific at intermediate depths (1000-2000m) experienced a rapid switch from low-oxygen to high oxygen conditions. This JAMSTEC/IPRC collaboration aims to identify the mechanisms that led to these major reorganizations of ocean circulation. Analyzing a suite of simulations conducted with the MIROC, LOVECLIM and CCSM2 models, it was found that a collapse of the Atlantic Meridional Overturning that occurred between 17000 and 15000 years before present, led to a substantial cooling of the North Pacific and an increase in surface salinities. The resulting higher surface density triggered deep winter-time mixing in the Gulf of Alaska and the Bering Sea. Reducing stratification in these regions leads to a surface mass convergence, shedding of Kelvin and Rossby waves and a subsequent readjustment of the entire western boundary current system. The simulated high oxygen concentrations are consistent with the observed high abundance of *A. weddellensis* in BOW-9A in the North Pacific (a species that thrives in oxygenated waters) and the low abundance of *B. pacifica* and *R. mexicana* (which prefer low oxygen conditions).

JII Theme 7 Data management, data serving, product development

The goal of Theme 7 is to establish an efficient, distributed and integrated Data Management (DM) and Data Server System (DSS) infrastructure for Indo-Pacific climate research (JAMSTEC, IPRC, and other partners/nodes), and to produce products for research and applications covering a wide range of time scales and processes.

In FY2007 the DM and DSS infrastructure at IPRC was

improved to offer new output formats such as animations and Google Earth files. Numerous new data holdings were added, including results from several OFES simulations. In addition, IPRC has made progress in FY2007 on Argo products, which are also in support of the collaborative (with JAMSTEC) Pacific Argo Regional Center.

1.3.3 Progress in the Integrated Ocean Drilling Program (IODP)

The global environmental change, earth interior dynamics, and microbial organisms at the bottom of the sea, IODP was progressed for researches in collaboration with the Ministry of Education, Culture, Sports, Science and Technology (MEXT) and Japan Drilling Earth Science Consortium (J-DESC). Japanese science community worked together in the decision mechanism of IODP-MI and the Science Advisory Structure (SAS). The IODP Domestic Science Committee and three projects selected by open participation (¥10,000,000 in total) were supported making effective drilling proposals. Eight IODP SAS committees and panels, and relevant conferences and the organization of the IODP Domestic Implementation Committee were also supported to contribute to international science community.

- Travel funds ¥15,573,000 was provided to 103 on-board researchers who participated in IODP expeditions and meetings as a part of our promotion activity of IODP.
- In two days, total 9,586 people visited Chikyu public opening in Shingu, Wakayama Prefecture, now the total number of visitors reached 70,000 people. Following this event, the International Symposium was held with 760 participants. In addition, outreach activities were proactively conducted: 23 press releases, the portal site operation, “Discover the Earth” magazines, “Sand for Students”, and exhibitions at academic conferences and science museums.
- IODP-MI approved the IODP Program Plan for U.S. fiscal year 2008. IODP expeditions using Chikyu, long-term borehole observatory, system development, core repository at the Kochi Core Center, and outreach (dissemination and enlightenment) activities were implemented as planned in FY 2007 according to the program plan.



Scientific Technology Panel (STP)



Public opening of Chikyu



Sand for Students in Arita River, Wakayama Prefecture

1.3.4 Promotion of research activities by external funds

A total number of research projects by external funds obtained were 174 in FY 2007 (vs. 169 in FY 2006), among which competitive funds supported 148 research projects (vs. 137 research projects in FY 2006), the Grant-in-aid for Scientific Research 128 research projects (vs. 118 research projects in FY 2006), other competitive funds 20 research projects (vs. 19 research projects in FY 2006) and non-competitive funds 26 research projects (vs. 32 research projects in FY 2006).

* Main new research projects include;

Science-in-aid for Scientific Research for 53 projects, Special Coordination Funds for Promoting Science and Technology for 1 project, Core Research for Evolutional Science and Technology (CREST) for 1 project, Global Environmental Research Funds for 4 projects, Innovative Program of Climate Change Prediction for the 21st Century for 2 projects, Program of Installing a Shared Facility for Creation and Innovation in Cut-edging Research for 1 project, Research Project for Utilizing Advanced Technologies in Agricultures, Forestry and Fisheries for 1 project, Grant for Development of Advanced Technologies Related to Housing and Building for 1 project and various private aid programs such as the Mitsubishi Foundation, etc. for 7 projects.

* Active efforts were continuously made to obtain external funds not only for research and development projects but also for development of human resources and dissemination of research findings (Nippon Foundation Grant-in-aid; "Cooperation with the Science Museum for holding exhibition of marine-earth science").

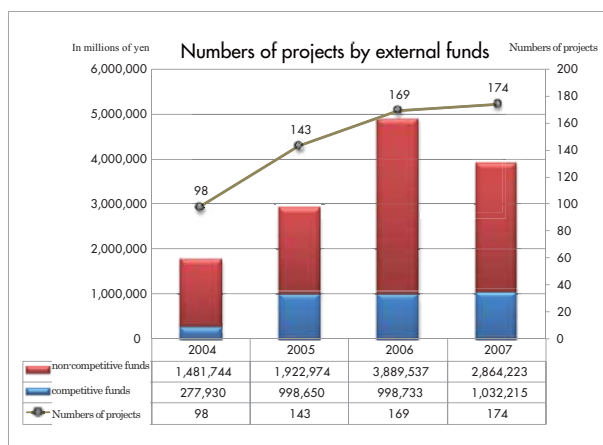
* We also aggressively applied to not only competitive research funds but also other funds for entrusted research and private funds (12 programs from private aid and 5 programs from funds for entrusted research and joint research).

* After a working group within JAMSTEC reviewed the guideline (practice standard) formulated by the Ministry of Education, Culture, Sports, Science and Technology of managing and auditing the expenditure of public research funds in research institutions, we built within JAMSTEC and applied a practical effective system for preventing research funds from illicit spending as asked by the guideline such as installation of various reliable structures within JAMSTEC for preventing research funds from unauthorized use, implementation of various rules and the like starting with establishing the rules related to managing research funds in competitive funds and the like and modifying the standard for activities and behaviors in

research, development and installation of the preventive measures for illicit spending, establishment of various consultation services, enhancement of homepages inside and outside the JAMSTEC.

* Since the indirect expenses applied by competitive funds are allocated as the expense required for improving environment of the research and development as the whole JAMSTEC and its function and for managing the operation of research, we established the rules of the "Guideline of allocating the indirect expense involving the competitive funds" and "operation manual related to spending of indirect expense involving competitive funds" (decided by the Board) and decided each research centers with the fund procured can allocate and use a half of the indirect fund allocated according to the expenditure plan autonomously prepared. Since this institutionalization encouraged active acquisition of funds for a better research environment, each researchers and research centers were given an incentive of actively acquiring competitive funds, thus generating circumstance for striving to acquire competitive funds.

* As responding to the operation of "Office-Ministry Common Electronic Management System for Research and Development (e-Rad)" installed in Ministry of Education, Culture, Sports, Science and Technology in order to promote elimination of irrational duplication and excessive concentration of competitive funds and the like and simplify procedures for registration and management of the information of researchers and for efficient job application, we further installed an efficient system within JAMSTEC as well as established the "Operational manual for applying external funds such as competitive funds and the like" in order to promote smoother processing of application to competitive funds and a system for each centers to absolutely confirm efforts by researchers for promoting applied projects in conjunction with response to the e-Rad system and consistency of using the grants for managing applied projects with the mid-term goal and plan of JAMSTEC.



* Numbers of projects by external funds

2. Promotion of research and development achievements

2.1 Main achievements of research and development

· We presented the following achievements of our research and development activities.

(total number for all centers) (ratio of peer-reviewed reports: 73%)

Peer-reviewed papers	English: 709, Japanese: 52, other 1 (FY 2006, English: 563, Japanese: 43)
Other reports presented in publications	English: 112, Japanese: 169 (FY 2006, English: 108, Japanese: 118)
Papers presented at academic conferences	International: 812, Domestic: 1,092 (FY 2006, International: 655, Domestic: 840)

· We held a total of 166 events such as symposia and research achievement presentations (including 9 international symposia and 75 workshops held within JAMSTEC).

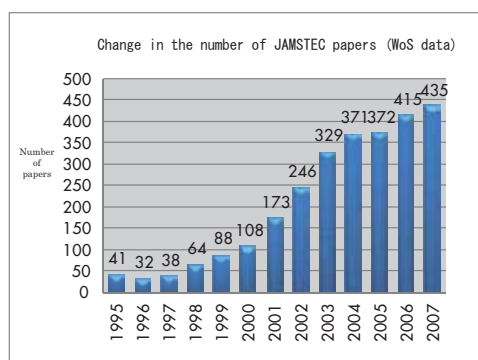
· We won a total of 21 awards in Japan and abroad in FY 2007.

· We enhanced the contents and pages of our research exchange information journal "INNOVATION NEWS," and published 3 issues of the journal throughout the year.

· We held the FY 2007 Annual Symposium "JAMSTEC 2008" and welcomed 302 visitors.

· We co-hosted industrial, academic and governmental collaboration events in Japan such as meetings for promotion of cooperation between industry, academia and government, and disseminated our research achievements through exhibits at the events.

· We continued observation using Long-term Deep Sea-Floor Observatory No. 1 (off Cape Muroto) and No. 2 (off Kushiro-Tokachi), and delivered the data from seismographs and tsunami recorders to the Japan Meteorological Agency and other organizations.



[Reference] Change in the number of papers according to Web of Science

* In calendar years

* Uses Thomson's "Science Citation Index Expanded (1995-)"

2.2 Public relations activities

· We updated the JAMSTEC bulletin, the pamphlets of JAMSTEC-owned research vessels and equipment and the pamphlets and other materials for children, and distributed them. In addition, we disseminated information such as research achievements via our web pages. For facility tours, we received visitors through applications made by telephone and on the Internet.

· The Yokosuka Headquarters was toured by groups of a total of 5,972 people (190 groups), and 153 individual visitors. The Yokohama Institute for Earth Sciences was toured by groups of a total of 4,342 people (292 groups), and 2,024 individual visitors. The institute also welcomed 1,115 attendants for open seminars and 54 participants in a children's experimental lab during summer vacation. The Global Oceanographic Data Center (GODAC) (closed on Mondays) was toured by groups of a total of 5,738 people, and 8,030 individual visitors. The center also hosted five GODAC seminars (515 attendants) and three ocean classes (136 participants). The Hatsushima Oceanographic Museum (closed on Tuesdays) was opened throughout the year. The gallery on the second floor of the Earth Science Museum in the Yokohama Institute for Earth Sciences regularly updates its exhibits, and conducted three project exhibitions in this fiscal year. The Hatsushima Oceanographic Museum was extensively renovated for the first time since the opening, and reopened on March 21, 2008.

· The Agency showed our deep sea research vessel "KAIREI" to the public at the Kamaishi Port in order to provide a public exhibition of our vessel (June 9, 2007; 1,775 visitors). Prior to this, we conducted a lecture (June 8, 2007; 95 attendants). We also showed the ocean research vessel "NATSUSHIMA" to the public at the Naha Port (June 17, 2007; 228 visitors) and the scientific research vessel "TANSEI-MARU" at the Otsuchi Port (November 3, 2007; 251 visitors). In addition, the Agency showed the deep sea drilling vessel "CHIKYU" to the public at the Shingu Port (February 10 and 11, 2008; 9,586 visitors), and also conducted an international symposium for the opening of CHIKYU (February 9, 2008; 760 attendants). As a commemoration of the 10th anniversary of their service, we showed the oceanographic research vessel "MIRAI" to the public (March 30, 2008; 2,214 visitors) and the deep sea research vessel "KAIREI" (March 30, 2008; 2,503 visitors), and held a commemorative symposium (March 29, 2008; 215 attendants) at the Yokohama Port.

· The Agency showed the facilities of the Yokohama Institute for Earth Sciences (April 21, 2007; 929 visitors) and the Yokosuka Headquarters (May 12, 2007; 3,168 visitors) to the public as part of the Agency's activities related to the Science &

Technology Week. The Agency also showed the facilities of the Mutsu Institute for Oceanography (July 22, 2007; 746 visitors) and the Kochi Institute for Core Sample Research (November 3, 2007; 650 visitors) to the public.

- As for publications, we issued "JAMSTEC NEWS (Natsushima)" 12 times throughout the year.

In addition, we issued "Blue Earth," an informational journal on oceans and the earth for the public, 6 times throughout the year, and a special edition on "Blue Earth" and "MIRAI" and another on "KAIREI," both of which celebrated the 10th anniversary of their services. The Agency's web pages were drastically remodeled at the end of FY 2006, and the pages received approximately 10 million hits throughout the FY 2007.

- Last fiscal year, the Agency published a booklet titled "Oceanic Science for Beginners" with a subsidy of the Nippon Foundation as the first publication of the JAMSTEC BOOK series, and distributed it to middle schools and high schools across Japan. In the current fiscal year, we worked on the procedure for allowing the booklet to be sold at online bookstores in order to promote its sale to the public. In addition, the Agency produced a picture book for children "A Great Earth Adventure of a Whale" in order to spread our research achievements in oceanic sciences and technologies as the second JAMSTEC BOOK publication.

- In this fiscal year, the Agency held two seminars in the series of "Ocean and Earth Institute", as the first seminar event organized by the Public Relations Section. The first seminar entitled "Global Warming Class for Businessmen - the World Crisis is about to Erupt" was held at the Uchisaiwaicho Hall in Chiyoda Ward (July 31, 2007; 105 visitors). The second seminar "Exploration of Earthquakes from Oceans" was co-hosted with the Nagoya City Science Museum at its Science Hall (January 12, 2008; 209 visitors).

- As for our major support through exhibits for science museums and other institutions, the Agency conducted exhibitions including a project exhibition "Past, Present and Future of Creatures in the Sagami Bay" at the National Science Museum (period: April 17 to June 17, 2007), a project exhibition "Tropical Oceans Perceived through Fossils" at the Natural History Museum and Institute, Chiba (period: June 30 to September 2, 2007), a special exhibition "Surprising Contents of the Earth!" at the Kobe Science Museum (period: July 14 to August 20, 2007) and a special exhibition "Mystery? Exploring Deep Seas" at the Notojima Seaside Park Aquarium (period: December 25, 2007 to March 2, 2008).

- In addition, the Agency provided support through year-round exhibits for institutions such as the OSTEC Exhibition Hall, the Tsukuba Expo Center and the Marine Science Museum. In

addition, we provided cooperation to the OSTEC Exhibition Hall for its complete renovation, and built a new exhibition booth for "CHIKYU" at the Hachinohe Marine Science Hall (Marient). The Agency also conducted a questionnaire among science and other museums throughout Japan as a study tool for implementing promotional and educational activities that meet the needs for marine science and technology. We will continuously strive to extensively provide opportunities for learning by conducting exhibitions and seminars more strategically.

- The Agency held the 10th "Draw Your Dreams of the Ocean on a Postcard" contest for children across Japan (call-for-entry period: November 30, 2007 to January 31, 2008; total number of applications: 18,626, consisting of 18,363 applications in the drawing category and 263 applications in the CG category). In addition, we provided hands-on embarkation experience, which corresponds to the supplementary prize of the previous contest, at the Kagoshima Bay from August 15 to 17, 2007, and 16 pairs of the winning children and their parents (32 people) experienced the site of an oceanic survey and shipboard life.

2.3 Intellectual property activities

State of intellectual property right acquisition: The figures in the parentheses represent those for FY 2006.

- Number of patent applications: 35 (30), including 18 (12) foreign applications

- Joint patent applications as achievements of joint research activities with private companies: 14 (14)

- Foreign applications: 15

- Number of patent registrations: 21 (4)

- Waivers: 7 (8). The Employee Confirmation Invention Committee reviews whether or not the patents owned by the Agency should be maintained every three years.

- Number of intellectual property rights owned by the Agency as of end of FY 2007: 61 patents, 12 trademarks, and 11 program copyrights

Appropriate management of intellectual property rights:

- To respond to diversification of intellectual properties and promotion of their utilization, and to establish a strategic structure for managing intellectual properties, the Agency revised our regulations related to intellectual properties.

- Consultations on inventions from researchers: approximately 50. The Agency strived to convert promising inventions into rights and sort out inventions through efforts such as finding seeds and creating inventions. In addition, we worked to promote consciousness toward the securing of rights by holding an explanatory meeting on intellectual properties.

Utilization of intellectual properties:

- To promote patent distribution, the Agency publicized the patents and the likes that we own by utilizing exhibitions and pamphlets.
- To achieve social contribution of our research achievements and creation of innovations, the Agency set up a granting system called "Program for Developing and Promoting Practical Application" that supports practical application. In FY 2007, we supported three research projects, and with one of these projects, we succeeded in helping the team to create and sell a product.
- The Agency continuously provided various supports to the Forecast Ocean Partnership LLP (limited liability partnership), which is the first JAMSTEC venture.

We have obtained 900 new isolated strains and 38 types of deep-sea saline mud, and currently store 6,800 deep-sea microbe strains, saline mud as the source for isolating deep-sea microbes, and 443 organic species in liquid nitrogen as of the end of YF 2007. We provide these strains to companies in accordance with a joint research agreement.

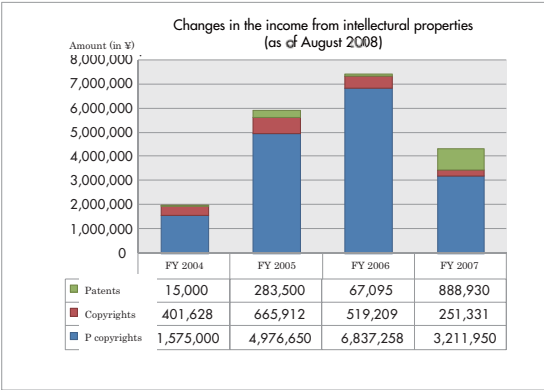


Fig. 2 Changes in the income from intellectual properties
* Including anticipated amounts within FY 2007

		Number of patents owned	Number of applications in 2007	Patents pending
Patents	Domestic	46 (6)	17	93
	Foreign	8 (30)	18	56

	Number of IP rights owned	IP rights pending
Utility models	0	0
Trademarks	12	2
Program copyrights	10	0

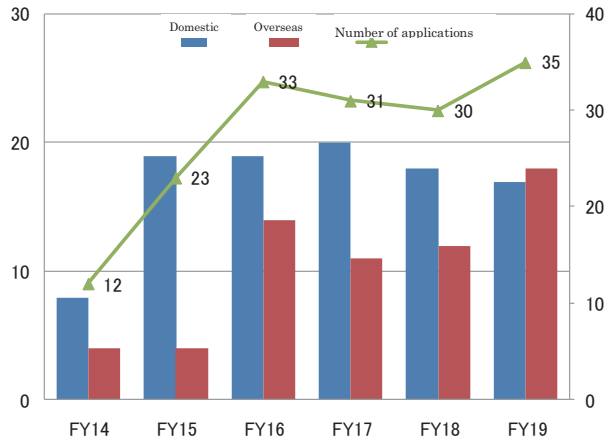


Fig. 1 Report on the current status and the numbers of the intellectual properties owned by JAMSTEC

3. Cooperation in operation of vessels for academic researches

We operated and managed the vessels that the Agency owns while managing the operation of the vessels in an integrated manner and continuously collaborating and cooperating with the Ocean Research Institute of the University of Tokyo, in order to achieve safe and efficient operation of academic research vessels. In addition, to deepen the understanding of ocean research among the public, the Agency showed "TANSEI-MARU" to the public on November 3 (Otsuchi, Iwate).

(1) Operation records of academic research vessels

For the operation plan for academic research vessels, the Cooperative Research Vessel Steering Committee of the Ocean Research Institute of the University of Tokyo, which serves as a shared-use body for researchers across the country, invites research project proposals and draws up a draft plan, and then the Agency's board of directors approves and determines the plan. Based on this operation plan, the Research Vessel Operation Department operates two academic research vessels as vessels voluntarily operated by the Agency.

1) Academic research vessel "TANSEI-MARU" (hereafter called "TANSEI-MARU")

"TANSEI-MARU" performed 31 operations in Japanese waters. In addition, the vessel performed trial and training voy-

ages after the annual survey. In FY 2007, "TANSEI-MARU" performed voyages accounting for a total of 262 days (266 days in the initial plan). Fig. 1 shows the cruise track map, and Table 1 shows the operation record for FY 2007.

2) Academic research vessel "HAKUHO-MARU" (hereafter called "HAKUHO-MARU")

"HAKUHO-MARU" performed 12 operations in the western North Pacific, the Mariana Ridge, the Indian Ocean and the Antarctic Sea in addition to Japanese waters. In addition, the vessel performed trial and training voyages after the annual survey. In FY 2007, "HAKUHO-MARU" performed voyages accounting for a total of 271 days (265 days in the initial plan). Fig. 2 shows the cruise track map, and Table 2 shows the operation record for FY 2007.

(2) Ensuring the safety and security of vessels

The Agency collected information such as meteorological information, security information of ports of call and information on legal changes, and sent such information to academic research vessels in order to ensure their safety and security.

(3) Appropriate operation structure (crew support)

The Agency appropriately deployed crew according to the operation plan in order to prevent trouble in observation research.

(4) Maintenance and operation of vessels and observation facilities and equipment

To cope with the aging of "HAKUHO-MARU" and "TANSEI-MARU," the Agency performed intensive repairs of the

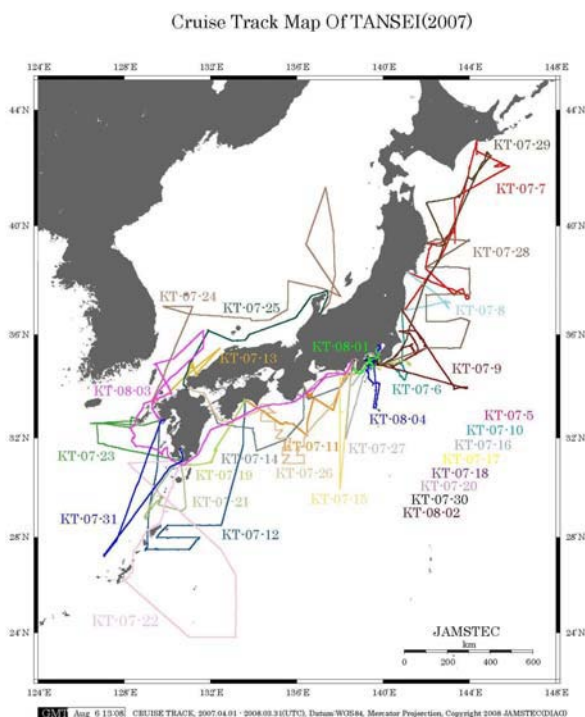


Fig. 1 Cruise track map of "TANSEI-MARU"

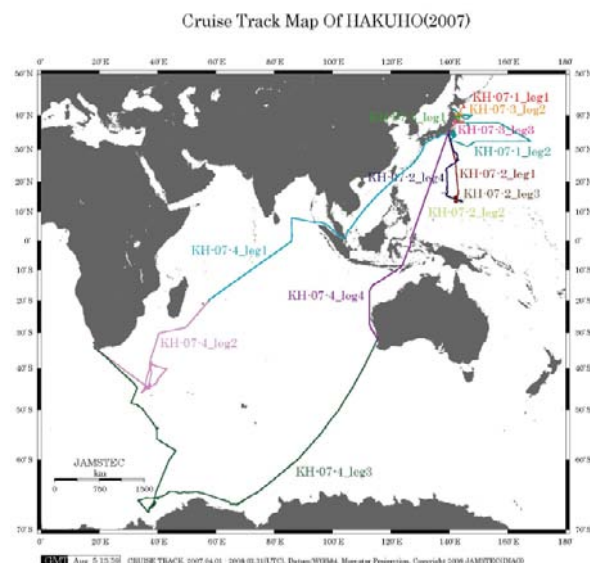


Fig. 2 Cruise track map of "HAKUHO-MARU"

vessels during the annual survey work period. For the observation equipment installed on the vessels as well as the lab-related facilities, the Agency performed partial improvements through consultation with the Ocean Research Institute of the University of Tokyo. In addition, we conducted performance check tests with focus on checking the basic operations of vessels and checking performances of research and observation systems.

1) "TANSEI-MARU"

For "TANSEI-MARU," the Agency changed its designation to a "non-international ship" (ship to which the ISPS code does not apply) after deliberation with the Ocean Research Institute of the University of Tokyo.

In this connection, we rewrote the load line indication. We also performed other maintenance and improvement works such as the replacement of the decrepit fridge-freezer of the laboratory, installation of a navigation information PC in the chief researcher office and the provision of an inboard LAN.

2) "HAKUHO-MARU"

For "HAKUHO-MARU," the Agency updated the winch controller and replaced the No. 4 winch. Since the folding crane controller has aged and it was difficult to procure the maintenance parts, a new whole controller was replaced. We purchased a motion sensor for the multi-beam echo sounder.

(5) Conduct of the observation support operation

The Agency maintained the observation support structure, and deployed at least one crewmember for each voyage.

1) "HAKUHO-MARU"

For "HAKUHO-MARU," the Agency provided on-board research support and land support for a total of 389 man-days (previous fiscal year: 322 man-days).

2) "TANSEI-MARU"

For "TANSEI-MARU," the Agency provided on-board research support and land support for a total of 318 man-days (previous fiscal year: 433 man-days).

(6) Collaboration and cooperation with the Ocean Research Institute of the University of Tokyo

To strengthen the collaboration with the Ocean Research Institute of the University of Tokyo, the Agency held liaison meetings on the operation of the academic research vessels to adjust opinions on the issues related to the operation (meetings were held five times in FY 2007).

Researchers and other staff from the Agency participated in the Cooperative Research Vessel Steering Committee of the Ocean Research Institute of the University of Tokyo, and its subordinate "Operation Working Group," "Vessel Working Group" and "Observation Working Group" as committee members, while the Research Vessel Operation Department participated in these committees as an observer, to present necessary proposals. In addition, captains and those in charge of onshore operations of the Research Vessel Operation Department participated in formulating the operation plan for FY 2008 to make the plan efficient and suitable for full-year operation.

In implementing the operation plan, the Agency organized a discussion several months prior to each research voyage and the meeting immediately before the voyage on the coming voyage in order to facilitate collaboration between the parties involved including the Ocean Research Institute of the University of Tokyo, onboard researchers, crew and the Agency's onshore division. The Agency also provided cooperation in the following operations to deepen the collaboration.

a) In the "Blue Earth '08" project, the Agency was provided with cooperation by the Ocean Research Institute of the University of Tokyo in the form of posters introducing the research achievements.

b) In cooperation with the Ocean Research Institute of the University of Tokyo, we conducted an event "We Love Oceans! Female Researchers Active in the Field of Ocean Science - A Study Visit to Hakuho-Maru" as an aid project for selection of scientific career options for female mid- and high-school students by the Ministry of Education, Culture, Sports, Science and Technology.

(7) Measure to achieve research vessels that can be used more easily

To accurately identify the requests of onboard researchers, the Ocean Research Institute of the University of Tokyo collects their opinions, and actively provides support for the vessels and dock works while maintaining close contact with the staff at the Research Vessel Operation Department.

H20.4.3

[illegible]

Table 2 Operation record of “HAKUHO-MARU” in FY 2007

H20.4.3

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE
April																															
	Oyashio region, Chishima, western North Pacific (Leg.1) KH-07-1(67days)															(Leg.1)										(Leg.1)					

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31						
	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE						
July	Class 2 intermediate inspection work																			Performance check trial voyage										Harumi							
																				[Completion]																	
Aug	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI						
	Harumi		←		Mariana (Leg.1) KH-07-2(59days)										→					Guam		←		Mariana (Leg.2) KH-07-2(59days)										→		Guam	
Sep	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN							
	←					Mariana (Leg.3) KH-07-2(59days)										→					Guam		←		Mariana (Leg.4) KH-07-2(59days)										→		/

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31						
	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED						
Oct	→	Harumi									Harumi	←					Off the Tohoku area-Off the Boso area (Leg.1) KH-07-3(41days)																				
																									Shiogama												
Nov	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI							
	Off the Tohoku area (Leg.2) KH-07-3(41days)										→				Off the Tohoku area (Leg.3) KH-07-3(41days)																						
Dec	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON						
																	Harumi	←	Indian Ocean, Antarctic Sea (Leg.1) KH-07-4(93days)																		

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU
Jan																															
Feb	FRI	SAT	SUN	MON																											
Mar	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON

4. Provision of use of facilities and equipment to those who conduct research and development or academic research on science and technology

4.1 Provision of use of test research facilities and equipment such as research vessels and deep sea research systems

In FY 2007, the Agency faced various constraints in service days of our vessels due to many standby situations to avoid typhoons and bad weather as well as the steep rise in crude oil prices, which has been a social problem since FY 2006. However, the Agency was able to minimize the impact of these adversities on our survey and research activities by working on economical vessel operation through optimization of the voyage plan and adoption of economical navigation speed.

Topics on the operation of vessels and survey/observation activities in FY 2007 included an emergency survey conducted by the deep sea research vessel KAIREI to contribute to disaster control by observing aftershocks of the Niigataken Chuetsu-oki Earthquake in July 2007, the film shooting and collection of articles left on the sea bed by remotely-operated vehicle "HYPER-DOLPHIN" and deep ocean floor survey system "DEEP TOW" as support for search concerning the collision between Aegis destroyer "Atago" and fishing boat "Seitokumaru," and the discovery of a hydrothermal eruption accompanying a chimney by remotely-operated vehicle "HYPER-DOLPHIN" at the world's shallowest point (200 m depth) on the Wakamiko submarine volcano in the Kagoshima Bay.

To deepen the understanding of oceanic research among the public, the Agency provided hands-on embarkation experience with the research vessel "KAIYO" and showed the research vessel "NATSUSHIMA" to visitors, as part of the facilities of the Yokosuka Headquarters opened to the public on May 12. In addition, the Agency showed the deep sea research vessel "KAIREI" to the public on June 9 (Kamaishi, Iwate), the research vessel "NATSUSHIMA" on June 17 (Naha, Okinawa) and the oceanographic research vessel "MIRAI" on July 22 (Sekinehama, Aomori) at ports of call. We also hosted an open symposium celebrating the 10th anniversary of services of the oceanographic research vessel "MIRAI" and the deep sea research vessel "KAIREI" at the Nisseki Yokohama Hall on March 29, and showed the vessels to the public on March 30 (Yokohama, Kanagawa).

In addition, we held a report meeting on the achievements of deep sea research and the "MIRAI" public invitation research in March 2008 in the form of "Blue Earth '08," and a total of 1,040 people participated in the two-day event.

Since the research plans in the public invitation for deep sea research and for use of "MIRAI" will end in FY 2008, we

have formulated "Five-Year Guidelines for Research on Oceans and the Earth," which consist of research plans for FY 2009 to 2013, and decided to start a new public invitation system in FY 2008.

1) Formulation of an annual research implementation plan

a) Public invitation system for deep sea research

For deep sea survey and research activities, the "Deep Sea Research Promotion Committee" (hereafter called the "Promotion Committee"), the "Deep Sea Research Planning Committee" (hereafter called the "Planning Committee") and the "Deep Sea Research Implementation Plan Coordination Working Group" (hereafter called the "Coordination Working Group") examine project proposals received at the Agency, and lay out research implementation plans.

The Agency called for proposals for the FY 2008 deep sea survey and research projects via the website for one month in July 2007. The vessels and equipment to which the public invitation was applicable included the manned research submersible "SHINKAI 6500," the support vessel "YOKOSUKA," the remotely operated vehicle "KAIKO 7000II," the deep sea research vessel "KAIREI," the remotely operated vehicle "HYPER-DOLPHIN," the research vessel "NATSUSHIMA" and the deep ocean floor survey system "DEEP TOW." In addition, the Agency also called for proposals for surveys with survey line recommendations using the MCS (multi-channel seismic reflection survey system) installed on "KAIREI" while placing several limits such as the waters to be surveyed. A total of 78 project proposals were received from 69 applicants at the Agency. The Planning Committee examined and ranked the proposals, and the Coordination Working Group formulated an annual research implementation plan (draft) based on the examination and ranking. As a result, 49 project proposals were selected. In November 2007, the Promotion Committee deliberated the annual research implementation plan (draft). The plan was then adjusted after the FY 2008 budget was determined, and finally approved at the board meeting held in February 2008.

b) Public invitation system for "MIRAI" cooperative use projects

For research voyages with the oceanographic research vessel "MIRAI," the Agency calls for proposals for major projects for the respective fiscal year from our research centers in accordance with the "MIRAI" Long-Term Observation and Research Plan (five-year plan from 2004 to 2008), and the "MIRAI" operation internal review meeting and the "MIRAI" review committee examine the collected proposals to determine the

adoption of the major project proposals. In addition, the Agency also calls for proposals for related projects, and the "MIRAI" operation review committee determines the adoption of the proposals.

As with the FY 2008 "MIRAI" Research Projects, the Agency called for proposals via the website for one month in July 2007. A total of 83 project proposals were received from 38 applicants at the Agency. In September 2007, the "MIRAI" operation review committee selected 77 project proposals, and they were approved at the board meeting held in February 2008.

c) Exclusive economic zone (EEZ) application

In accordance with the provisions of Part 13 of a United Nations convention on the law of the sea (UN Convention on the Law of the Sea), the Agency asked a total of 35 countries (including Taiwan), along which 13 voyages planned for FY 2007 were to be made, to apply to the Ministry of Foreign Affairs for facilitation of the survey voyages, as the necessary procedure for conducting surveys in the exclusive economic zone (EEZ) of the countries along the waters to be researched.

2) Operation of vessels and deep sea survey systems

a) Research vessel "NATSUSHIMA" (hereafter called "NATSUSHIMA")

"NATSUSHIMA" conducted underwater cruises for surveys using the remotely-operated vehicle "HYPER-DOLPHIN" off the Tokai area, in the Izu-Ogasawara waters, off Cape Noma & in the Kinko Bay, in the Nansei Islands waters, off Enshunada, in the Kumano Trough, off the Kushiro area, off the

Shimokita Peninsula, in the Toyama Trough and in the Sagami Bay as part of the projects adopted through public invitation for deep sea survey proposals and for internal use. In addition, "NATSUSHIMA" conducted independent surveys in the Izu-Ogasawara waters. The research vessel also provided hands-on embarkation experience to children who had dreams about oceans and whose paintings were accepted for the 9th National Ocean Dream Painting on Postcard Contest for Children, for three days from August 15 to 17 using the remotely-operated vehicle "HYPER-DOLPHIN," in order to encourage them to experience the site of an oceanic survey and shipboard life. The vessel also conducted performance check test voyages concerning the annual survey. "NATSUSHIMA" performed voyages accounting for a total of 242 days (259 days in the initial plan) in FY 2007. Fig. 1 shows the cruise track map and Table 1 shows the operation record for FY 2007.

b) Research vessel "KAIYO" (hereafter called "KAIYO")

"KAIYO" conducted operations including surveys for delineating Japanese continental shelves using equipment such as an MCS (multi-channel seismic reflection survey system)/OBS (ocean bottom seismograph), and independent surveys using equipment such as the deep ocean floor survey system "DEEP TOW" and a piston corer, in the Nankai Trough, in the Izu-Ogasawara waters, in the Suruga Bay & off Kashimanada, in the Sagami Bay, off the southern Honshu area, off the Boso area & eastward off the Shimokita Peninsula and in the Okinawa Trough. In addition, the vessel conducted performance check test voyages concerning the annual survey. "KAIYO" performed voyages accounting for a total of 253 days (251 days in the initial plan) in FY 2007. Fig. 2 shows the cruise track map and Table 2 shows the operation record for FY 2007.

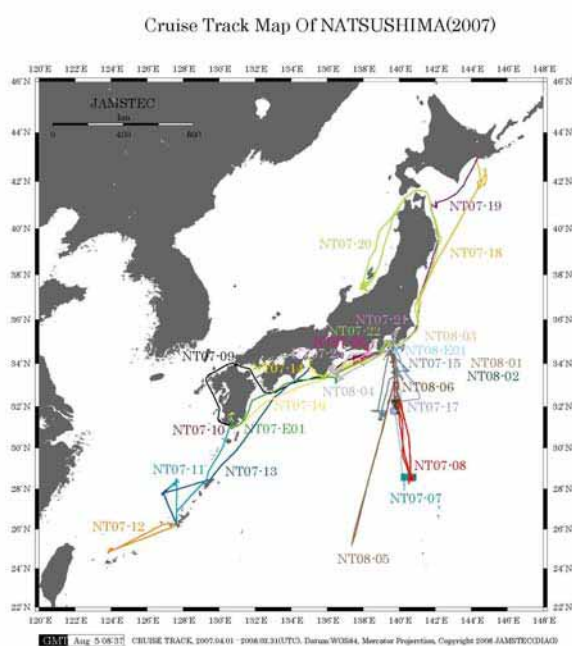


Fig. 1 Cruise track map of "NATSUSHIMA"

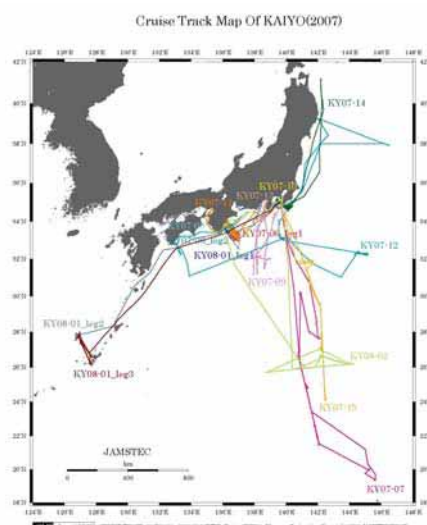


Fig. 2 Cruise track map of "KAIYO"

c) Support vessel "YOKOSUKA" (hereafter called "YOKOSUKA")

"YOKOSUKA" conducted underwater cruises for surveys using the manned research submersible "Shinkai 6500" in the Sagami Bay, in the Kuril Trench & off the Kushiro area, in the Northwest Pacific Ocean & off the Sanriku area and in the Nankai Trough as part of the projects adopted through public invitation for deep sea survey proposals and for internal use. In addition, "YOKOSUKA" conducted independent surveys in the Sagami Bay & in the Izu Islands waters, in the Okhotsk Sea and in the North Pacific Ocean. The vessel also conducted performance check test voyages concerning the annual survey, "SHINKAI 6500" trial/training operations, and technical development operations using "URASHIMA" and other equipment. "YOKOSUKA" performed voyages accounting for a total of 240 days (269 days in the initial plan) in FY 2007. Fig. 3 shows the cruise track map and Table 3 shows the operation record for FY 2007.

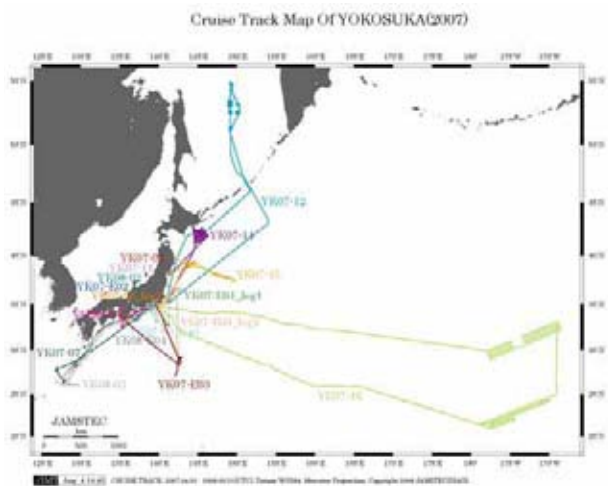


Fig. 3 Cruise track map of "Yokosuka"

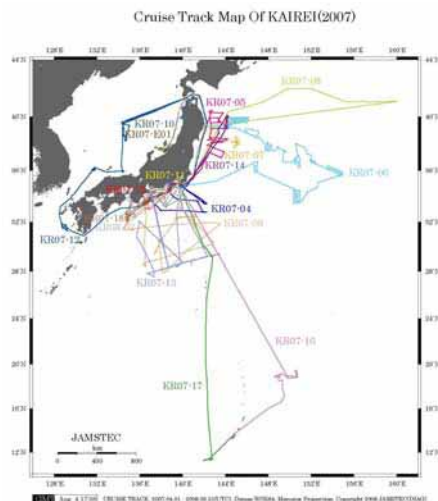


Fig. 4 Cruise track map of "KAIREI"

d) Deep sea research vessel "KAIREI" (hereafter called "KAIREI")

"KAIREI" conducted underwater cruises for surveys using the remotely operated vehicle "KAIKO 7000II" in the Northwest Pacific Ocean, the Japan Trench and the Nankai Trough as part of the projects adopted through public invitation for deep sea survey proposals and for internal use. In addition, the vessel conducted independent surveys including surveys for delineating Japanese continental shelves in the Japan Trench, the Northwest Pacific Ocean, the Izu-Ogasawara waters, the Nankai and Higashi-Nankai waters, the Nankai Trough, the Japan Sea, the East China Sea and the Mariana Islands waters.

The vessel also checked the operation of the MCS (multi-channel seismic reflection survey system) that was updated to a more accurate system and conducted trial and training operations of the remotely-operated vehicle "KAIKO 7000II" in a performance check test voyage concerning the annual survey. The deep sea research vessel "KAIREI" performed voyages accounting for a total of 246 days (261 days in the initial plan) in FY 2007. Fig. 4 shows the cruise track map and Table 4 shows the operation record for FY 2007.

e) Oceanographic research vessel "MIRAI" (hereafter called "MIRAI")

"MIRAI" conducted operations consisting of "Atmospheric and oceanographic observation research in tropical areas" in the western tropical Pacific Ocean, the Indian Ocean and the Northwest Pacific Ocean, "Observation research on the thermal/material transport and its change in tropical areas, and observation research on the identification of the chemical environmental change in oceans" in the North Pacific Ocean and the Pacific Ocean, and "Research on chemical substance circulation, and research on the biocenotic structure and the food

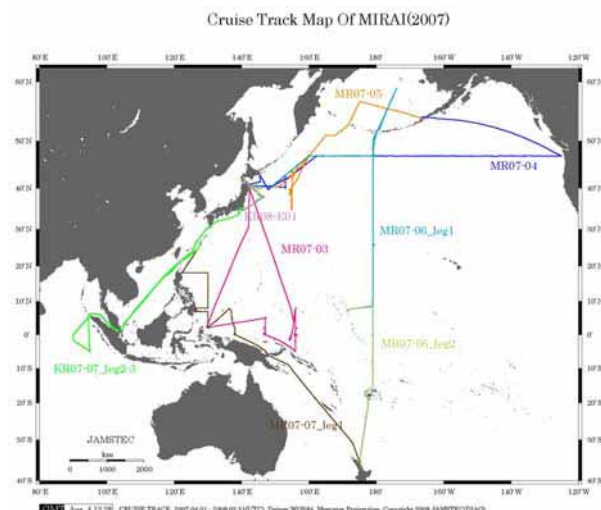


Fig. 5 Cruise track map of "MIRAI"

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Table 2 Operation record of “KAIYO” in FY 2007

H20.3.31

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	
	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON		
April					Yokohama										KY07-06 OKODT		Nankai Trough															
					Loading		Shift																				Outside the Ogasawara Port					
														07:45													08:00					
May	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	
								Shift	J																							
															Agency open house																	
June	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT		
														J		Marine technology school																

Table 3 Operation record of "YOKOSUKA" in FY 2007

H20.3.31

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE
April																															
May																															
June																															
July																															
Aug																															
Sep																															
Oct																															
Nov																															
Dec																															
Jan																															
Feb																															
Mar																															

Table 4 Operation record of “KAIREI” in FY 2007

H20.3.31

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31						
	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON							
April		J		J	KR07-04 7K	J	Trial training underwater cruise												J	Landing Loading	Shift	Yamashita			Shift	KR07-05 MCS PC the Japan Trench											Shift
					Loading 7K		Diving ① Temporary anchorage in Shimizu #377	Diving ② #378	Diving ③ #379	Diving ④ #380	Diving ⑤ #381	Diving ⑥ #382	Diving ⑦ #383		Diving ⑧ #384																						
May	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU						
	J Landing Loading		JShift Departure				Shift									KR07-06 7K OBEM Northwest Pacific									Shift	Kamashita			Diving ① #385	Diving ② #386	Diving ③ #387		Kamashita				
June	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT							
	Kamashita	KR07-07 7K the Japan Trench					Diving ① #388	Diving ② #389	Diving ③ #390	Diving ④ #391	Diving ⑤ #392	Diving ⑥ #393	Landing Loading	Open boxes in Kamashita	KR07-08 7K Northwest Pacific					Shift	Diving ① #394	Diving ② #395	Spare	Shift	Shift	Shift Izu-Yamashita Port	J			KR07-09 MCS Izu-Ogasawara							
																										J	Continental shelf survey										

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE
July					KR07-09 MCS Izu-Ogasawara																			J 08:40 Landing OBS Loading	Shift Arriving at Yamashita		Departing Yamashita				
Aug	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI
					KR07-10 MCS/OBS Nankai, Higashi-Nankai (Off the Shima Peninsula)										Shift	Nigata	Nigata OBS Landing	KR07-E01 MCS/OBS Nigataken Chuetsu-oki Earthquake emergent survey							Shift	J	OBS Landing ROV Rigging	Quay test			
Sep	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	
	J 08:00	KR07-11 ROV Sagami Bay						J ROV Landing		Shift	Shift	KR07-12 SOS PQ Mid/southern Japan Sea & East China Sea										Shift	Shift	Shift	Shift	J	SGS PC Landing	Landing Dolly Loading	Shift Yamashita	Departing Yamashita	

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31								
	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED								
Oct											KR07-13 MCS/OBS Izu-Ogasawara																											J Landing Loading 7K Dolly Shift	新 港
Nov	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI									
	J Shift	KR07-14 TC Off the Bonfile near the Japan Trench										J	KR07-15 7K PC Nankai Trough												J	J Shift	KR07-16 OBEM Mariana												
		Shift Diving ① #396	Diving ② #397	Diving ③ #398	Diving ④ #399	Diving ⑤ #400	Diving ⑥ #401	Shift	08:50 Landing Loading							Diving ① #402		Diving ② #403	Diving ③ #404	Diving ④ #405	Landing Loading	Yamashita			Yamashita	Shift	Shift	Shift											
Dec	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON								
	Shift	Quam	Quam					Shift	Shift	Shift	J				J		KR07-17 ROV The Mariana Trench										J Temporary anchoring	Shift	Harumi										
											Landing Loading							Diving ① #406	Diving ② #407	Diving ③ #408	Diving ④ #409				Landing Loading	Harumi													

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31						
	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU						
Jan							Harumi					J Shift	Preparation for 2008 refreshment work					J Shift		Harumi				Shift	“KAIREI” annual survey (56 days)												
																						Harumi															
Feb	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI								
												“KAIREI” annual survey (56 days)																									
Mar	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON						
												“KAIREI” annual survey (56 days)																KR08-02 Performance check trial voyage									

Table 5 Operation record of “MIRAI” in FY 2007

H20.3.31

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31				
	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON					
April	◀-----"MIRAI" periodical survey (40 days)-----▶																																		
May	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU				
														MR07-02 Performance check trial voyage																					
June	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT					
	Haohinh e Sakineha ma							MR07-03 Western tropical Pacific																											
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31				
July	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE				
	MR07-03 Western tropical Pacific																									MR07-04 North Pacific									
Aug	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI				
				MR07-04 North Pacific																															
Sep	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN					
							MR07-05 Northwest Pacific																												
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31				
Oct	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED				
	Haohinh e Sakineha ma													MR07-06 North Pacific waters																					
Nov	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI					
					MR07-06 North Pacific waters																				MR07-06 Pacific waters										
Dec	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON				
				MR07-06 Pacific waters																															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31				
Jan	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU				
				MR07-07 Western tropical Pacific																															
Feb	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI						
			MR07-07 Indian Ocean																																
Mar	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON				
	MR07-07 Northwest Pacific Leg3																																		
		Sakine hama																																	

intake ecology of zooplanktons" in the Northwest Pacific Ocean. In addition, the vessel collected the drifting model 4 TRITON buoys in the MR07-03 voyage, and collected KEO buoys of the Pacific Marine Environmental Laboratory (PMEL), which had not been collected due to bad weather in the MR07-03 Leg 3 voyages, on the way to Yokohama, although such collection was not included in the initial plan. The vessel also conducted a performance check test voyage concerning the annual survey. "MIRAI" performed voyages accounting for a total of 288 days (265 days in the initial plan) in FY 2007. Fig. 5 shows the cruise track map and Table 5 shows the operation record for FY 2007.

f) Manned research submersible "SHINKAI 6500" (hereafter called "SHINKAI 6500")

"SHINKAI 6500" performed underwater cruises for surveys in the Sagami Bay, in the Kuril Trench & off the Kushiro area, in the Northwest Pacific Ocean & off the Sanriku area and in the Nankai Trough as part of the projects adopted through public invitation for deep sea survey proposals. Since a trouble occurred in the hatch of the pressure hull of "SHINKAI 6500" in the beginning of the fiscal year, the submersible shelved four underwater cruises scheduled for the May to September period, examined the cause and took measures to solve the trouble, and then performed a trial operation for checking safety. The submersible performed one of the four shelved operations at the end of March in the Nankai Trough. "SHINKAI 6500" performed a total of 55 underwater cruises consisting of 23 underwater cruises for surveys (54 in the initial plan) and 32 trials and training underwater cruises (17 in the initial plan).

g) Remotely-operated vehicle "HYPER-DOLPHIN" (hereafter called "HYPER-DOLPHIN")

"HYPER-DOLPHIN" performed underwater cruises for surveys off the Tokai area, in the Izu-Ogasawara waters, off Cape Noma, in the Kinko Bay, in the Nansei Islands waters, off Enshu-nada, in the Kumano Trough, off the Kushiro area, off the Shimokita Peninsula, in the Toyama Trough and in the Sagami Bay as part of the projects adopted through public invitation for deep sea survey proposals. The remotely operated vehicle "HYPER-DOLPHIN" performed a total of 158 underwater cruises consisting of underwater cruises for surveys accounting for 90 days (96 days in the initial plan) and trial and training underwater cruises accounting for 32 days (26 in the initial plan) (two or more underwater cruises were performed in one day in some cases).

h) Remotely-operated vehicle "KAIKO 7000II" (hereafter called "KAIKO 7000II")

"KAIKO 7000II" performed underwater cruises for surveys in the Northwest Pacific Ocean, the Japan Trench and the Nankai Trough as part of the projects adopted through public invitation for deep sea survey proposals. "KAIKO 7000II" performed a total of 33 underwater cruises consisting of underwater cruises for surveys accounting for 17 days (23 days in the initial plan) and trial and training voyages accounting for 16 days (13 in the initial plan).

3) Ensuring the safety of vessel activities

The Research Vessel Operation Department consults with the Research Safety Committee, the Department/Laboratory Manager Meeting and the Board Meeting about each vessel activity before it is conducted, in addition to performing procedures for approval/notification of relevant regulations. For maritime activities, the Research Vessel Operation Department appointed personnel in charge of respective activities in accordance with the "Safety and Health Regulations" defined by the Agency, and responded to accidents and other trouble under the "Guidelines for Emergent Responses to Accidents/Trouble" established by the Agency. To cope with pirates, the department took necessary actions based on the "Basic Policy on Measures to Cope with Pirates" defined by the Agency. In addition, the department performed waters adjustment as necessary.

4) Maintenance of vessels and deep sea research systems

For each vessel, the Agency conducted legal annual survey and repair work and provided maintenance works for the vessel body and engine-related components in order to maintain the basic performance of the vessel. For research submersibles, the Agency performed legal annual surveys and works to maintain their performances. For remotely-operated vehicles, the Agency performed works related to convenience, maintenance and function improvement.

In addition, the Agency conducted works related to function improvement that were discussed at the Survey/Observation Functions Review Meeting. For vessels, the Agency conducted performance check test voyages mainly for checking the operation and performance of survey observation equipment installed on vessels, and onshore operation tests, submergence tests and trial underwater navigations for deep sea research systems (research submersibles, remotely operated vehicles, etc.). Thus, the Agency completed all the required inspections and tests.

To improve services for researchers, the Agency installed DVD recorders in all vessels in order to provide images of

research submersibles and remotely operated vehicles on DVDs.

As a measure to cope with the aging and degradation of vessels and deep sea research systems, the Agency started studying possible solutions including an inboard LAN in order to update the electronic navigation system and workstations for the central processing unit of each vessel. Additionally, the Agency noted an event in which the hatch of "SHINKAI 6500," which exceeded 1,000 underwater cruises in the previous fiscal year, was lifted higher than normal. The submersible temporarily stopped its operation to adjust the hatch and confirm safety, and then resumed the survey operation.

Notable works we performed are as follows:

a) "NATSUSHIMA"

- Support of digital transmission for the "Himawari" image receiver
- Installation of a DVD recorder and a DVD duplicator

b) "KAIYO"

- Support of digital transmission for the "Himawari" image receiver
- Installation of a simplified voyage data recorder (SVDR)
- Inspection, repair and reinforcement of the hull structure
- Purchase of a kitchen microwave
- Purchase of an engine supercharger
- Replacement of the gyrocompass for the DPS
- Replacement of the basin for researchers

c) "YOKOSUKA"

- Maintenance of the onboard gravimeter
- Replacement of the decoder for the DGPS
- Measure to solve the aging and degradation of the main engine
- Installation of a DVD recorder and a DVD duplicator

d) "KAIREI"

- Modification in response to higher accuracy of the multi-channel seismic reflection survey system (MCS) (Fig. 1)
- Maintenance of the onboard gravimeter
- Replacement of the decoder for the DGPS
- Partial replacement of carrier modules for the multi-narrow beam echo sounder (MBES)
- Replacement of the radar
- Installation of a DVD recorder and a DVD duplicator



Fig. 1 Streamer cable for the new MCS

e) "MIRAI"

- Partial replacement of uninterruptible power supply units (UPS)
- Purchase of a highly elastic joint of the main engine
- Replacement of the acoustic doppler current profiler (ADCP)
- Installation of an SVDR
- Replacement of the semi-dry lab ultrapure water production system
- Production of a winch pedestal for the IONESS towing net

f) "SHINKAI 6500"

- As a hatch lifting event was noted, set up an external committee and conducted a causal investigation, took a countermeasure and conducted trial underwater cruising to confirm safety.
- Replacement of the underwater telephone
- Study of an optical electric complex feed-through connector (Fig. 3)



Fig. 2 "MIRAI" ADCP (with the acoustic window removed)



Fig. 3 Optical electric complex connector for "SHINKAI 6500"

g) "HYPER-DOLPHIN"

- Performance check of the precision bathymetry mapping system
- Operation check of the cable extender

h) "KAIKO 7000"

- Purchase of a part for the controller in the onboard maneuvering board
- Operation check of the cable cutter
- Integrity check of the primary cable and the secondary cable
- Study of increasing the transmission capacity of the optical transmitter

i) Other equipment

- Development of a 11,000-m free-fall type camera bottom sampling system (Fig. 4)
- Improvement of the function of the 6,000-m class sonar "DEEP TOW"



Fig. 4 11,000-m free-fall type camera bottom sampling system

5) Implementation of observation support operations

To support research activities and related onshore research operations, the Agency collected requests from all research divisions, commissioned research support companies with operations, and provided instructions and supervision for these operations. Major topics are as follows (research support accounting for approximately 19,000 man-days):

- Research support concerning deep sea survey and research projects and other activities
- Research support concerning oceanographic research vessel "MIRAI" voyages
- Research support concerning academic research vessels "HAKUHO-MARU" and "TANSEI-MARU" voyages
- Onshore support at the Mutsu Institute for Oceanography, the Yokohama Institute for Earth Sciences and the Global Oceanographic Data Center in Nago

6) Operation of TRITON buoys

In FY 2007, the Agency took over the observation of TRITON buoys placed in FY 2006 at a total of 17 points, consisting of 15 points in the Pacific Ocean and 2 points in the Indian Ocean. For the 2 points (buoys No. 17 and 18) in the Indian Ocean, the Agency completed the pilot research using TRITON buoys, and shifted the research work to an operation in the form of research commissioned by the Ministry of Education, Culture, Sports, Science and Technology using the m-TRITON buoy, which the Marine Technology Center developed two years ago.

Major topics are as follows:

a) In a commissioned research project "Indian Ocean Moored Buoy Network Initiative for Climate Studies" (Ministry of Education, Culture, Sports, Science and Technology), our Agency is responsible for the development, improvement and operation of the buoy system, which is required under a sub project. In a mooring trial with the m-TRITON buoy in a real sea situation, which started last fiscal year in the Indian Ocean, we conducted long-term mooring for a total of 432 days and confirmed that the buoy had no problem even in a remaining strength test. Based on these findings, we started a full-scale operation of m-TRITON buoys at two observation points in the Indian Ocean.

b) The TRITON buoy No. 17 in the Indian Ocean, which was equipped with a reinforced tower last year as a measure to prevent it from being stolen, successfully continued observation for one year without being stolen and produced a good result, although it showed a trace that indicates a ship or the like was moored to it at some point during the observation service. Based on this result, the Agency plans to deploy m-TRITON buoys in sequence at those observation points where buoys are frequently stolen.

c) Since the m-TRITON buoy adopts a slack mooring method, the length of the mooring cable is approximately 1.4 times the water depth. If it were possible to maintain and replace the buoy float and the underwater sensor using this cable on the sea, it would contribute to reducing the cost including buoy operation and vessel operation. Therefore, using "MIRAI" and assuming buoy maintenance on the sea, we conducted a test of raising a wire cable (500 m) for an m-TRITON buoy's float and underwater sensor immediately beneath the buoy on the deck of the vessel while keeping the buoy moored. As a result, we confirmed that it was possible to maintain m-TRITON buoys on the sea.

d) The Agency produced a prototype of a water

temperature/depth sensor, which we intend to domestically produce, for mass-production. We will check the long-term stability of the sensor in the future. In addition, we commenced the development of a system for evaluating this sensor.

7) Observation at the Okinotorishima Island

The Agency has conducted continuous observation of meteorological and hydrographic conditions at the Okinotorishima Island. This fiscal year, our vessel departed to the Okinotorishima Island to perform periodical survey and maintenance as with last year. However, the vessel headed back halfway in order to provide cooperation in an investigation of a maritime accident involving a Maritime Self-Defense Force ship and a fishing boat, and thus, the inspection and maintenance of this fiscal year was put off.

8) Data sampling from vessels

The Agency sorted out inventory information such as contents and recipients of acquired data and samples for each of the projects involving vessels and manned and unmanned vehicles that were determined through public invitation of proposals.

9) Formulation of "Five-Year Guidelines for Research on Oceans and the Earth"

Since the research plans adopted through public invitation for proposals for deep sea survey and research projects and proposals for use of "MIRAI" will end in FY 2008, the Agency formulated "Five-Year Guidelines for Research on Oceans and the Earth," which define the research plans for the period between FY 2009 and FY 2013, and decided to start a new public invitation system in FY 2008. The research plans were formulated based on opinions that the Agency extensively collected through a symposium (Future Perspective Symposium) (Fig. 1) and via the website.

In addition, the Agency prepared a "Report on the Achievements of the Deep Sea Survey and Research Activities and the Observations with 'MIRAI'," which summarized reports on the achievements of the current research plans from the respective working groups formed by research fields.

10) Holding the "Blue Earth '08" event

The Agency held a symposium event entitled "Blue Earth '08," which consisted of "MIRAI Symposium" and "SHINKAI Symposium," at the Yokohama City University in order to present the achievements of our research voyages concerning "MIRAI" and deep sea survey and research operations. The "MIRAI Symposium" was held for the 11th time while the "SHINKAI Symposium" was held for the 24th time. In the two-

day event, a total of 227 presentations were made (212 in last fiscal year), and a total of 1,040 people (1,278 people in last fiscal year) participated in the event. In this year's event, the Agency presented the "Five-Year Guidelines for Research on Oceans and the Earth" (Fig. 1), which will apply from voyages to be determined through public invitation for FY 2009, and hosted a special seminar entitled "Truth of Global Warming - a Scientific Overview and the Strategy of the 4th IPCC Evaluation Report, Which Won the Nobel Peace Prize -" and seminars and workshops entitled "For the Achievement of a New Oceanic Research Vessel," "Present State and Future of the Census of Marine Life II," etc., in addition to presenting our achievements. The Agency also examined "Blue Earth '08" poster presentations from young researchers (35 years or below), and honored four excellent applicants. In addition, we conducted a questionnaire among the participants in order to make the "Blue Earth" event of the next fiscal year more productive.

11) Holding a Marine Technology Center workshop (MIND)

Serving as the secretariat, the Long-term Observation Group of the Department of Applied Ocean Engineering held a workshop once a month in order to comprehensively improve technologies by feeding back opinions and problems raised



Fig. 10 Future Perspective Symposium



Fig. 11 Presentation of the "Five-Year Guidelines for Research on Oceans and the Earth"

from the sites of actual vessel operations and research observations and share information or exchange opinions required to conduct research support operations, under the concept of "oceanic knowledge (information) and discussions." In FY 2007, the group hosted a total of 10 workshops including special lectures inviting Mr. Yukihiro Nakahara, Standing Director, Research Institute for Ocean Economics, and Dr. Kazuo Kobayashi, Professor Emeritus of the University of Tokyo, and over 80 people from inside and outside the Agency participated in each workshop.

12) Maintenance and operation of test research facilities and equipment such as a pool

(1) Common facilities

a) Maintenance and shared use of the common facilities and equipment related to research

The Agency performed legal inspection and voluntary inspection of the common facilities and equipment. Additionally, the Agency performed operation of the common facilities and equipment, and maintenance and management of the buildings.

Major common facilities and equipment

Hyperbaric experiment water chambers, medium-size hyperbaric experiment water chamber, small-size hyperbaric experiment water chamber, wave motion tank, ultrasonic tank, diving training pool, observation winches, diving simulator, quay, etc.

2) Lending of facilities and equipment

The Agency smoothly performed internal procedures as the contact for internal and external inquiries on the use of common facilities and equipment and applications for using them. In addition, the Agency provided technical support and performed operation and management of the facilities in response to requests.

(2) Operation of the analytic labs

The Agency performed operation, maintenance and management of a transmission electron microscope, a field-emission-type scanning electron microscope, an electron probe microanalyzer, etc. In addition, the Agency also made efforts for the improvement of related technologies and technological development while taking into account the needs of researchers in order to support electron microscope technologies, which are progressing day by day.

(3) Machine shop

The Agency performed maintenance, services and management of the machine tools in order to maintain them in favorable conditions and promptly respond to requests from researchers and technicians. Additionally, we installed an NC milling machine as new equipment.

a) Production/repair: 343 items in total

b) Design support: 73 items in total

(4) Conduct of technical training and other programs

The Agency launched a comprehensive technical training system (marine technology school) aimed at fostering Agency staff and observation engineers who provide research support on the sea and ground and transmitting the technologies cultivated at the Agency to next generations. A total of 35 participants completed the beginners' course. In addition, we provided training for diving professionals, mainly officials of public institutions such as police and fire departments, for 21 times by making the most of the diving technique of the Agency, and a total of 387 participants completed the training. The Agency also delegated our staff as lecturers to external organizations 5 times. In addition, we conducted our unique helicopter underwater escape training for mostly "CHIKYU" crew for 21 times, and trained 261 staff members in order to secure their safety.

4.2 Provision of use of the Earth Simulator

○ Operation of the Earth Simulator

To efficiently operate the Earth Simulator and make it available to researchers, the Agency performed system maintenance, user management and resource allocation. As of the end of the fiscal year, the number of registered users was 756 and that of jobs submitted throughout the year was 122,801, and almost 90% of the nodes were used throughout the year. On the other hand, complete system down due to fault occurred only once in FY 2007 and node failures occurred 17.9 times per month on average (215 times throughout the year), and the down time of the nodes excluding scheduled maintenance was only 0.83% of the whole.

From the viewpoint of information disclosure, the Agency discloses the state of the system operation including the above failure cases on our website (<http://www.jamstec.go.jp/es/jp/status/index.html>).

In addition, the Agency hosted an explanatory meeting and a workshop (April 16 and 17) and prepared or improved various guides and technical documents in order to improve utilization techniques of the Earth Simulator users. The Agency also strived to increase convenience for the users by setting up a full-time technical contact to provide solution support as techni-

cal assistances such as programming concerning various problems in the use of the Earth Simulator (technical ones such as submission of requests, how to use files, and efficient programming technique) as our technical support including programming.

We increased the transfer rate by performing organization, integration and equipment update of networks related to the Earth Simulator, and updated the server for visualization designed to perform post-processing including visualization at high speed. In addition, we increased immediacy in information provision to users and improved efficiency of the updating operation through efforts such as adoption of a content management system to the website for user support.

We also strengthened the information dissemination structure through efforts such as building a repository of research achievement databases using the Earth Simulator in order to allow users to easily access the databases from search engines and paper search systems on the website (<https://www.jamstec.go.jp/es-repository/portal/jp/index.html>).

○ Examination and adoption of a next system

To improve the cost performance of the Earth Simulator in order to meet the increasing research needs for more reliable global warning forecasts and technological innovations, the Agency examined adoption of a next system. To discuss details including the performance based on a adoption policy that the Next System Planning Committee formulated in FY 2006, the Agency held “The Earth Simulator Next System Examination/Selection Committee” meeting eight times, and formulated a specification document and an adoption schedule. In formulating the specification document, the Agency complied with the policy for government procurement concerning the adoption of super computers. In the meantime, the Agency examined a bench mark program for appropriately evaluating the performance of large-scale computer systems including the next system through a joint research program “Technical Research on the Building of Large-scale Computer Systems” with RIKEN.

○ Enhancement of the promotion of the pay use of the Earth Simulator

The Agency enhanced the measures to promote use of the Earth Simulator among the industries that consider using the simulator on a paid basis, by introducing application software for the industry, full-time reception of applications for the pay use, newly establishing a prior evaluation system that allows the user to check the program operation for free in advance, and lowering the charge by 30% from the previous rate (FY 2006).

In terms of public relations, the Agency actively conducted activities such as distributing a press release on the above promotion policy, running booths at the Innovation Japan 2007(College Fair), which was aimed for industry-government-academia collaboration, and the CEATEC JAPAN 2007, which was a comprehensive exhibition of state-of-the-art IT and electronic technologies, providing a lecture at the Kansai Economic Federation's seminar, presenting achievements from industrial use of the simulator until FY 2006, and holding “The Earth Simulator Industrial Use Symposium” to contribute to benefiting society.

In addition, the Agency provided technical support for vectorization and parallelization as well as support that includes even algorithms in order to promote these industrial uses.

○ Achievements of the pay use of the Earth Simulator

In FY 2007, there were 10 applications for pay uses exclusive for achievements, consisting of 8 resulting in pay uses, and 2 ending in prior evaluation only (income from use charge: ¥22,068,000). For the “Research Project for Sustainable Coexistence of Human, Nature and the Earth,” which has been conducted as a research promotion program of the Ministry of Education, Culture, Sports, Science and Technology since FY 2002, the Agency conducted 7 research and development projects in FY 2006. In addition, the Agency adopted 5 projects as part of the “Program for Strategic Use of Advanced Large-scale Research Facilities” of the Ministry of Education, Culture, Sports, Science and Technology based on the policy for encouraging the industry to use large research facilities as promoted by the government in FY 2006. In FY 2007, we adopted 12 projects in the “Open Advanced Facilities Initiative for Innovation (Strategic Use by Industry),” which is a successor program to the above program, substantially increasing the number of projects using the simulator on a commissioned project basis. In addition, the Agency conducted 5 projects as part of the “Core Research for Evolutional Science and Technology (CREST)” of the Japan Science and Technology Agency. Thus, the achievements of accepting various Earth Simulator users including new users and industries through competitive funds are being made.

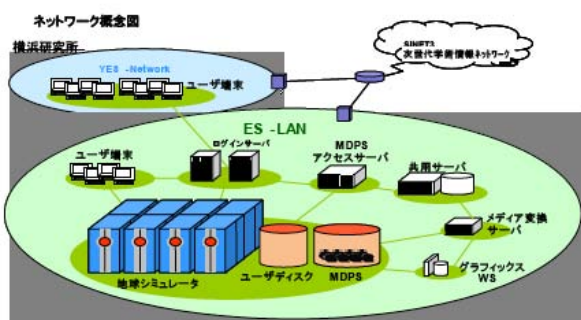
Examples of such achievements include the winning of CERI Best Paper Award by SRI Research and Development Ltd. (present Sumitomo Rubber Industries, Ltd.) and the joint application for a patent with Sumitomo Chemical Co., Ltd.

○ Selection of project and benefits to society

As for the projects for FY 2007, the Project Selection Committee (held on March 5, 2007) selected the projects based

on the allocation of calculation resources that were determined at the Plan Promotion Committee (held on January 29, 2007). As a result, a total of 42 projects consisting of 17 in the field of earth science, 2 in the field of computer science and 23 in the field of advanced creation were adopted. In addition, the Agency held the Earth Simulator Symposium in October 2007 to publicize the achievements of various projects to the public.

For remote access, security measures such as one-time password management with token cards and the limitation on connection source addresses are provided in addition to ordinary authentication.



4.3 D/V CHIKYU operation

- Following fiscal year 2006, overseas test drilling was conducted by external funds. Two riser holes and six upper riser holes (riser-less drilling section), including inclination drilling, were drilled in the Australian ocean area, which accumulated our experience and knowledge for international operations, upgraded the skills of crews, and improved the operation rate.
- After the overseas test drilling, scientific drilling was started from September as a part of the Integrated Ocean Drilling Program (IODP) for Nankai Trough Seismogenic Zone Experiments (NanTroSEIZE). Three expeditions nearly achieved the targets and obtained necessary data and core samples for researches and analyses: 33 holes were drilled with a total length of 12,800 meters, including logging-while-drilling (LWD) at five sites with a total measurements length of 4,272 meters, coring at six sites with a total length of 3,400 meters.
- Four preliminary surveys were conducted including precise seafloor exploration by Urashima in the Okinawa Trough and Sagami Bay, and core sampling offshore in Shimokita, Sagami Bay, and Boso offshore, which collected data from the ocean area where IODP drilling is planned.
- Kochi Core Center started to accept IODP core samples using Koazo, their own core management software. The Center evaluated sampling requests of NanTroSEIZE Stage 1 A expeditions and sent necessary samples. Educational courses were provided to IODP on-board researchers and prospective university students in cooperation with J-DESC.
- High-speed satellite communication networks between the vessel and land were built aboard the vessel. A data management software, J-CORES, has started the operation after development and improvement.

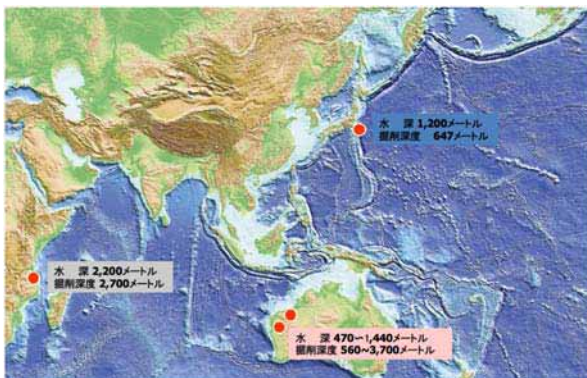


Fig. 1 Test drilling sites



On-board researcher observing a core by a magnifying lens

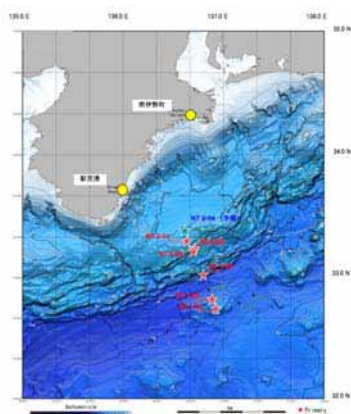


Fig. 2 Drilling sites in the Nankai Trough

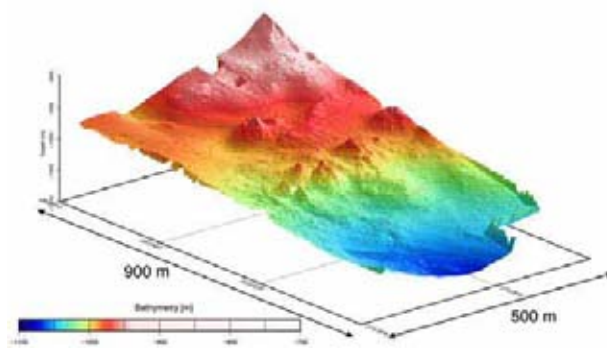


Fig. 3 Precise seafloor geography of Okinawa Trough by Urashima



Chikyu sailing out toward Nankai Trough



Discussion on LWD data



Core barrel 9.5 m long collected aboard



Cold storage in the Kochi Core Center

5. Training of researchers and engineers, and enhancement of their qualifications

- A total of 36 JAMSTEC researchers engaged in educational research activities as faculty members (24 professors, 12 associate professors) of collaborative graduate schools.
- The Agency delegated 2 external researchers, and newly selected 4 external researchers as candidates for next delegation.
- The Agency accepted a total of 103 researchers including students of collaborative graduate schools to contribute to human resource development.
- The Agency conducted a “JAMSTEC Internship” program as practical workplace training for university and graduate school students, and accepted 45 students (20 universities) at our 10 divisions.
- The Agency delegated a total of 181 lecturers for human resource development.
- Utilizing its diving technique, the Agency provided diving training 21 times for a total of 387 officials of public institutions such as police and fire departments.
- The Agency conducted unique helicopter underwater escape training for “CHIKYU” crew and support group members 21 times, and trained a total of 261 internal and external participants to secure their safety.
- The Agency launched a comprehensive technical training system (marine technology school) aimed at fostering Agency staff and observation engineers who provide research support onboard and onshore and transmitting the technologies cultivated at the Agency to next generations. A total of 35 participants completed the beginners' course in the first fiscal year.
- The Agency conducted a Marine Science School (24 participants in the student course) and a Science Camp (26 participants) for students of high schools and technical colleges. In addition, the Agency conducted a Marine Science School (14 participants in the teacher course) and a Marine Teachers School (8 participants) for teachers of middle and high schools. The Marine Teachers School is a training on the sea using the research vessel “KAIYO,” and was conducted for the first time this fiscal year. For university and graduate school students, the Agency held a marine science and technology school at the Yokosuka Headquarters (21 participants) in summer, and another at Okinawa in spring using facilities including those of the Global Oceanographic Data Center (25 participants), the Agency provided a workplace experience event for middle school and high school students (45 participants).

6. Collection, organization, storage and provision of information and documents

The Agency holds books (33,815 books in total) and videos (2,547 videos in total) at four bases including libraries of the Yokosuka Headquarters and the Yokohama Institute for Earth Sciences, and has provided electronic journals (approximately 150 kinds) and Japanese magazines (approximately 150 kinds). The Agency has collected 1,695 reference books in FY2007 additionally, which were specialized in Ocean and Earth studies. We also started offering journal articles offset service (approximately 800 requests for photocopying/fiscal year) of NII (National Institute of Informatics) in June, enhanced the scientific database “Web of Science,” which allows a large number of researchers to share. Workshops to instruct were periodically held for researchers, to support them using it in their studies.

We issued Annual Report written in Japanese and English. In addition, we published a scientific journal “JAMSTEC Report of Research and Development,” which contained 9 papers.

As for the information dissemination from our website, we disseminated information through updates more than once a week. Our website received approximately 10 million hits throughout the year.

For data and sample management, we formulated a Basic Policies on the Handling of Data and Samples that defines the handling of data and samples acquired using JAMSTEC facilities and equipment. We established and improved regulations on the handling of data and samples acquired with vessels and submersibles in order to implement the policy.

Concerning the “MIRAI Data Web” and the “Deep Sea Research Data Web,” the Agency received data accounting for a total of 93 cruises, which consisted of new cruises and past cruises. The number of data we received was 373; each kind of data acquired from each cruise was counted as one.

For quality management, the Agency continued to disclose quality-managed data among CTD observation data, and started quality management of data such as bottle-sampled seawater, primary production, meteorology and ship mounted acoustic doppler current profiler (ADCP).

From the data we store, 317 kinds of data (112 from MIRAI and 195 from deep sea research cruises) were publicized on JAMSTECs websites. From FY2007, we have started to publicize data of analyzed bottle-sampled seawater (Quality Controlled) and gravity data (converted to absolute value).

We also publicized approximately 50,000 deep sea images on the “Deep Sea Image Database” as a part of managing

images from deep sea researches. Approximately 60,000 images were converted into high-resolution digital images continuously to prevent degradation of negatives we hold and to have them effectively used.

A curator to manage rock samples was deployed and the and functions of the Rock Sample Database GANSEKI was improved. 6,400 meta data of rock samples were opened by the end of FY2007 (Fig.1).

In addition, we started electronically filing cruise reports and submersible dive track charts that the Agency holds.

The “MIRAI Data Web” received approximately 2.12 million hits (page views) in FY 2007. A total annual hits for the “Deep Sea Image Database,” the “Deep Sea Research Data Web (open to the public since FY 2005)” and the “Rock Sample Database GANSEKI (open to the public since FY 2006)” combined was approximately 3.07 million, of which effective hits excluding search robots and the likes accounted for approximately 890,000.

Other than downloading from data site databases, we provided 8 data, 17 images/videos and 5 samples (30 in total) to external users off-line in response to their applications for using them. The Agency performed approximately 150 kinds of services for users within JAMSTEC, such as preparation of bathymetric charts, provision of observation data and provision of deep sea image data.

Concerning the collaboration with external institutions, the Agency provided CTD data of “MIRAI” (for 1998 to 2003) to the Japan Oceanographic Data Center, and signed MOU with the UNEP (UN Environment Programme) Shelf Programme to start provision of cruise track data and other data from the Agency's observation cruises to the data search site operated by the Shelf Programme.

Data Integration and Analysis System (commissioned operation: collaboration with the University of Tokyo and JAXA) is an application-function development project that we have worked on which creates integrated data (as samples).

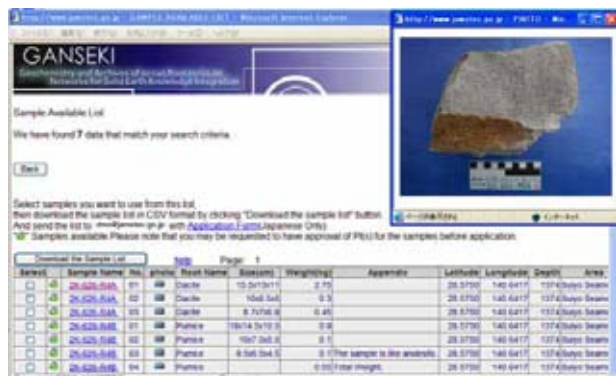


Fig. 1 Top page of rock sample database GANSEKI

This system is a part of the Earth Observation and Ocean Exploration System which is under the National Key Technologies, and we built a test website for data publication and distribution to open our data. Furthermore, we conducted research on needs for use of these data, and started examination for promoting extensive use of integration and analysis data, such as studying a possible method for integration between oceanic reanalysis data set with fishery data and for analysis of such data (Fig. 2).

We also made a research to find hidden demands to use JAMSTEC's data, needs of a data directory that covers all of the data sets which each research center in the Agency are publicizing and considered about system functions to consolidate and provide meta data information.

In conjunction with the Marine Biology and Ecology Research Program of the Extremobiosphere Research Center, we studied functions and made an infrastructure system for the Biological Information System for Marine Life; a website to provide integrated data about marine life that live in the deep sea (Fig. 3).

The Global Oceanographic Data Center (GODAC) created 2,300 digital masters of deep sea survey record images, encoded 1,907 digital master images, indexed 28,971 shots of encoded image data (disclosed approximately 14,000 shots of deep sea images on the web), digitalized and publicized 15,806 pages of periodicals and other publications, and digitalized 730 drawings and images including dive track charts, as its digital archiving operation. GODAC's website received approximately

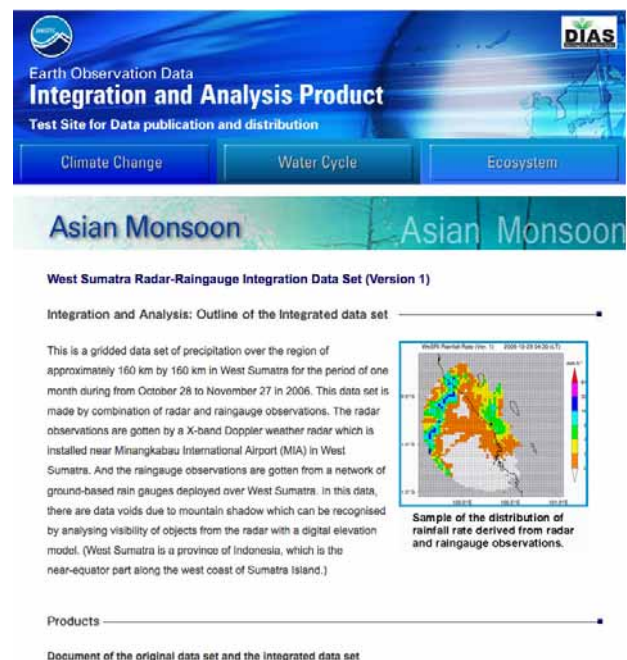


Fig. 2 Screen example of our web site that publicizes and provides earth observation data integration/analysis product

1.43 million hits.

JAMSTEC operates different two types of super computer systems to promote the various researches. SGI Altix 4700 is scalar-type parallel super computer system, and NEC SX-8R/24M3 is vector-type parallel super computer system. The Advanced Scientific Library (ASL) and Numerical mathematics and data analysis software (MATLAB toolbox) are installed into these systems in order to respond to the needs of research users. The super computer user support group accepts consultation concerning the program tuning and the application software.

We are operating the JAMSTEC network system as an information infrastructure. The Internet connects with SINET3 that the science information network operated by National Institute of Informatics (NII), and is providing a high-speed network environment. As the network service to the users, the e-mail system enhanced anti-virus system, and has strengthens the remote access service. In addition, we started newly wireless LAN service at the Mutsu Institute for Oceanography (MIO) and the Kochi Institute for Core Sample Research (KOCHI). The information security has become a critical issue in JAMSTEC, we checked information security guideline of the government's standards. In order to bolster information security, we are monitoring the network traffic to block unauthorized access to JAMSTEC computer system based on this guideline. We are also confirming the security vulnerability by checking the security level of the servers which open to the Internet.



Fig. 3 Image of a screen of Biological Information System for Marine Life

7. Evaluation

- Continuing from FY 2006, the Agency performed self evaluation of the operational performance of the whole Agency at the JAMSTEC Evaluation Committee. The evaluation result is publicized through the Agency's website.
- As for the self evaluation on the operational performances of research centers and the Kochi Institute for Core Sample Research, we efficiently performed evaluation by building a structure that allows the center heads to receive opinions of external experts (advisors) based on the evaluation structure reviewed in FY 2006.
- As for the evaluation of research projects, an external evaluation committee consisting mainly of overseas experts conducted interim evaluation of the global environment prediction research at the Frontier Research Center for Global Change.
- We reflected the result of the self evaluation, and the results of the evaluation by the independent administrative institution evaluation committee of the Ministry of Education, Culture, Sports, Science and Technology until FY 2006, on the budget and operation plans for FY 2008.

8. Information disclosure

- Number of requests for disclosure in FY 2007: 0
- In accordance with the law concerning the disclosure of information held by independent administrative institutions, we provided information via our website.
- To accurately respond to requests for disclosure of information, we formulated a response manual for the information disclosure contact, and provided training to the personnel in charge of information disclosure on how to respond and check the procedure.
- We provided training for new staff to learn the basic knowledge on document management and information disclosure.
- To contribute to appropriately managing personal information, we continuously provide basic education for new staff, and education to ordinary staff for deepening their understanding of personal information protection.
- We reviewed manuals as appropriate to enhance the personal information protection structure.

II. Promotion of efficient operations

1. Organization and administration

1.1 Organization

- In order to establish a system for the development of next-generation ocean exploration technology, the system of research programs of the Advanced Marine Technology Research Center at the Marine Technology Center was reviewed. At the same time, for effective and efficient research and development activities, related work, including the comprehensive observation system for submarine earthquakes, was transferred from the Department of Applied Ocean Engineering to the Division for Promotion of Development of Dense Oceanfloor Network System for Earthquakes and Tsunamis, unifying the research and development system for the Oceanfloor Network System.

- The General Coordination Group was set up in the Planning and Coordination Office of the Marine Technology Center, integrating the systems for efficient performance of general office tasks allocated to each Program and Department of the Marine Technology Center into the General Coordination Group, for more effective and efficient performance of those tasks. In addition, work related to the Convention on the Law of the Sea (including application for EEZ consent) which is in the International Affairs Division's charge, and work of regional-seas coordination which is in the charge of the Research Vessel management and Operation Department and the Center for Deep Earth Exploration, were grouped into work of regional-seas coordination in the broad sense of the term, and as the organizational unit charged with this work, the Regional-Seas Coordination Office was expanded and reorganized into the Regional-Seas Coordination Group, which was set up under the Planning and Coordination Office.

- Since transparency and neutrality in achieving compliance are required by the society, the Audit Office was reorganized into the Audit and Compliance Office. This new Office thus promotes work involved in compliance activities regarding laws and regulations, standards and the like as a whole. In addition, related work, including the whistleblower protection system, was also transferred from Administration Division to the Audit and Compliance Office, so that the Office is charged with developing measures to prevent occurrence of illegal acts in whistle blowing, research and other activities [FFP (Fabrication, Falsification and Plagiarism), misrepresentation of expenses and other acts] and with taking appropriate action against any illegal acts that may occur. Further in December, a Code of Compliance was formulated, expressing clearly the Agency's attitude toward fairness and transparency in the performance of work activities, primarily research and develop-

ment.

- Since safety and environmental management are closely related in the Agency's research and development activities, their unified management contributes to improving the reliability in the Agency. For this reason, the Safety Management Office was reorganized into the Safety and Environmental Management Office.

- Related work, including establishment of the information infrastructure and network management, was transferred from the Data Integration and Analysis Group of the Marine-Earth Data and Information Department to the Supercomputer System Planning and Operations Department, establishing a system for promoting in an integrated fashion information technology related work, which is the basis of the Agency's work activities.

- In order to perform efficiently work contracts entered into with overseas customers following the start of full-fledged operation of the Chikyu, all related work that had been distributed between the Planning and Coordination Office and the Science and Planning Department was assigned solely to the Science and Planning Department, and this Department was reorganized into the IODP Promotion Department. Besides, work of the two Groups in the Engineering Department was reviewed in response to efforts at the promotion of next-generation ocean exploration technology.

- In order for the Agency as a whole to deploy public relations measures more strategically, the public relations functions that had been handled independently by the Earth Simulator Center and the Center for Deep Earth Exploration were transferred to the Public Relations Division, establishing a system for performing coordinated public relations activities.

- At the Kochi Institute for Core Sample Research, the Subsurface Biosphere Research Group was set up to promote multifaceted research using core samples collected by the Chikyu. In addition, for steady performance of full-fledged transfer, control, distribution and other steps of IODP core samples, the Science Services Group has been additionally assigned the work of storing and controlling core samples.

- Following the establishment of the personnel system, it was decided to transfer work related to job assignment specified in the organization regulations from the Personnel Division to the Administration Division, making it the single unit charged with handling work related to organization, job assignment and responsibilities.

- For better functioning of the libraries, library work was separated from the work of the Public Relations Department of the Marine-Earth Data and Information Division, and assigned to the Library Division, which was newly set up. Also, the position of councilor in charge of planning and promoting library

work was created.

- With a view to promoting the "Promotion of Training and Securing Human Resources and of Their Activity" in the Third Basic Science and Technology Plan, it was decided that the Department of Applied Ocean Engineering of the Marine Technology Center be charged with developing high-level engineers in a systematic manner in the future and that in order to conduct effectively and efficiently training for the safety on board vessels and the like, including diving skills and escaping from a sinking helicopter for researchers aboard the Chikyu, skills training be concentrated in the Department of Applied Ocean Engineering and provided by the Department in an integrated manner.

- In order to present clear, long-term visions that will be necessary for Japan as a maritime nation to precisely respond to changing conditions in the country's economic society and marine environment as well as for the Agency to develop into a worldwide COE (Center of Excellence) in the fields of the ocean, the earth and the environment, and in order to strategically promote research and development for the realization of such visions, the Long-Term Vision Examination Team formulated a "New Exploration of the Frontiers of the Marine Earth."

- Meetings of the Conduct of Research Conference for the exchange of opinions between the Agency's president and the head of each Center were held regularly once a month.

- The Management Advisory Conference of knowledgeable people from outside the Agency met in February in order for the Agency to seek advice on its operation.

- A meeting of the Safety Conference was held to evaluate the results of safety and reliability activities of the Agency as a whole.

- In response to the Law Concerning the Promotion of Business Activities with Environmental Consideration, measures were taken to consider the environment fully in the Agency's activities, and the "Environmental Report of Japan Agency for Marine-Earth Science and Technology was prepared and published.

- In order to discuss greater work efficiency, the Work Efficiency Promotion Committee met, and it engaged in the business process reengineering activity, realizing the better work efficiency included in the medium-term goals defined for the activity. At the same time, in order to clarify the roles of the administrative organizational units and ensure better performance of their core work, the Committee prepared and formalized a Report on Business Process Re-engineering, Etc. in March of 2008.

1.2 Administration

- A new personnel system was introduced at the beginning of FY 2007, enabling the signing of multiple-year employment contracts with personnel with fixed terms of office and the granting of qualifications for long-term employment to them. In addition, on the basis of the job classification and grading system, the role of each worker were clarified, creating a unified evaluation system common to the Agency as a whole. In order to help these systems to become firmly established, various measures were taken. For the evaluation system which needs to be applied with particular care, training was conducted to improve evaluation skills.

- In accordance with the personnel-system regulations established in 2006, a personnel evaluation was conducted for the purpose of making the most of capabilities (human resources), developing human resources, building capabilities, and treating personnel fairly, thereby achieving the organization's goals, running the organization efficiently, producing personnel of high caliber and improving the competitiveness of the Agency and its members. The results of the evaluation will be reflected in data for use in the development of human resources and building of their capabilities and in promotions, pay raises, and other personnel and pay matters.

- In order for the personnel evaluation system to become firmly established in early stage, the training for evaluators (in managerial position) continued to be conducted.

- In accordance with the evaluation system based on the new personnel system, personnel evaluation for FY 2007 was performed. This evaluation system, consisting of two components, one concerned with the degree of role performance and the other with the evaluation of capabilities exercised, incorporates the MBO (Management By Objective) approach, enabling evaluation according to each employee's job. This system also includes personal interviews between the evaluator and the evaluatee at workplace, thereby promoting instruction, education and communication based on the results of evaluation. Following the modification of the evaluation system, an evaluation-based pay-raise system was introduced anew, realizing fair pay raises based on the employee's evaluation.

2. Promotion of the efficiency of operations

- At the Agency's organizational units performing general office tasks [Planning Department; Administration Department; Finance and Accounting Department; Safety and Environment Management Office; Marine-Earth Data and Information Department (Public Relations Division); Research Promotion Office and Planning and Coordination Office of each Center; and General Affairs Division of each Institute], "Business

Process Re-Engineering" is being performed aimed at greater work efficiency by eliminating work redundancy, clarifying work duties, improving (simplifying and standardizing) a variety of work, examining outsourcing of work, establishing the IT infrastructure, and taking other measures. In FY 2007, the second phase of this re-engineering project was performed in accordance with the procedures described below, and achieved certain results. In the promotion of this re-engineering project, in order for those involved to have the same awareness and thinking about work improvement and for their necessary skills to become firmly established, a total of five education and training sessions were conducted at the milestones in each procedure; once for personnel in managerial position, twice for those in immediate charge, and twice for both of them jointly. Further, other measures for steady progress of the project were also taken, including offering opportunities for personnel in immediate charge to meet and exchange their opinions and to make report on the progress. Still further, a "Business Process Re-engineering Task Team" was formed to put together proposals for themes for the re-engineering project across the Agency.

<Promotional procedures and results for FY 2007>

- In July of 2006, the Business Process Re-engineering project started, and it has since been conducted, mainly on the three subjects of "Improvement of Work Procedures," "Re-Engineering of the IT Infrastructure" and "Re-Engineering of General Office Task Organizations.

- On the subject of Improvement of Work Procedures, the "short-term improvement themes" and "medium- to long-term improvement themes" had been set in FY 2006, and work on these themes was performed at each relevant organizational unit in FY 2007. As a result, work on 423 short-term improvement themes and 115 medium- to long-term improvement themes were completed, reducing work loads by 12.8% (77,000 hours) compared with the applicable ones (607,000 hours worked by 339 workers) determined by an inventory of total work loads conducted in FY 2006.

- On the subject of Re-Engineering of the IT Infrastructure, the Agency-wide examination was made, and an implementation system was built for promoting "outsourcing" and the "establishment of the IT infrastructure." It was decided to start working on specific measures (outsourcing and the introduction of informatization) in FY 2008. This is expected to reduce work loads by 6.9% (41,000 hours) compared with the applicable ones.

- On the subject of Re-Engineering of General Office Task Organizations, a "Business Process Re-Engineering Task Team" was set up to examine drastic increases in general-

office-task efficiency and other matters, and the Team put together a proposal for "Needs-Based Organizations" that clarifies the responsibilities and roles of their constituents. It was decided to use this proposal when examining the new organization for an integrated corporation into which the Agency will be reorganized.

- "Important Policies for Administrative Reforms" (decided by the cabinet on December 24, 2005) mentioned in the Agency's plan for FY 2007 states that personnel expenses, among others, should be cut down. In order to first review the expenses of the Agency as a whole and finally achieve the goal of reducing such expenses by 5% or more compared with FY 2005 by FY 2010, reduction targets by organizational unit and item of expense were set. In FY 2007, personnel expenses were controlled to be within the amount that is reduced by 1.0% compared with FY 2006.

- Starting early in FY 2007, the base pay levels were lowered by an average of 4.8%; the system for raising pays beyond the limits was abolished; the shift to a fixed amount of crew allowances was made; the payment standard for family allowances was reviewed; regional allowances were introduced; and new long-distance travel allowances were newly created. Managerial position allowances were scheduled to be reviewed starting early in FY 2008, and the policy was laid down of formulating anew a payment standard based on job content, and of switching to a fixed amount of pay raises to curb seniority-based pay increases.

III. Financial statements

Statement of accounts for FY 2007

(In millions of yen)

Classification	Budget (A)	Final settlement (B)	Difference (A - B)
Revenues			
Grants for operating expenses	37,190	37,190	0
Subsidies for facilities expenses	810	810	0
Subsidy revenues	0	9	△ 9
Revenues from business operations	3,752	2,728	1,024
Revenues from contract work	157	7,601	△ 7,444
Total	41,909	48,337	△ 6,428
Expenditures			
General and administrative expenses	1,615	1,514	102
(General and administrative expenses excluding taxes and other public dues)	1,031	1,037	△ 6
Included personnel (in managerial position) expenses	718	554	165
Included non-personnel expenses	313	484	△ 171
Taxes and other public dues	584	476	108
Business operations expenses	39,327	40,084	△ 757
Included personnel (in operating position) expenses	2,542	2,535	8
Included non-personnel expenses	36,784	37,549	△ 765
Facilities expenses	810	789	21
Subsidized business operations	0	9	△ 9
Contract-work expenses	157	8,200	△ 8,043
Total	41,909	50,596	△ 8,687

* The total of the numbers for each column may not match the total at the bottom line because of rounding off.

IV. Short-term borrowed money

· Not applicable.

V. Disposal of important properties of planning of mortgage

· Not applicable.

VI. Disposition of surplus funds

· Not applicable.

VII. Others

1. Plans concerning facilities and equipment

On the deep-sea drilling vessel Chikyu, which started operating internationally in FY 2007, machinery necessary for drilling operations, and refrigerated containers and other fixtures for use in on-board storage of core samples were installed.

In the maintenance of the institute buildings and equipment, as measures against obsolete facilities and equipment, air conditioning equipment were renewed for the second straight year in this FY 2007. In addition, waterproofing work on external walls

and the like of various buildings was performed; compressors for use in diving-training facilities were renewed; and the inside work environment was improved by introducing IP telephones, for example.

2. Plans concerning personnel affairs

Personnel expenses, sought to be reduced by "Important Policies for Administrative Reforms" (decided by the cabinet on December 24, 2005), will be cut down by 5% or more compared with FY 2005 by FY 2010. To this end, the applicable personnel expenses for FY 2008, the final year for the current medium-term target period, were controlled to be within the amounts that are reduced by about 1% compared with the applicable ones for FY 2005.

The personnel system, full application of which started in FY 2007, was used to secure personnel of high caliber; assign personnel to appropriate positions; improve personnel's capabilities; train young researchers; increase personnel mobility; and manage personnel retiring at a fixed age and personnel with a fixed term of office in an integrated manner.

In order to realize a personnel treatment system that curbs seniority-based pay raises and treat personnel according to their service record, an evaluation-based pay-raise system was introduced. For steady implementation of the evaluation-based pay-raise system, personnel in managerial position were trained for improved evaluation skills.

In order to hire people of quality anew, jobs were posted on job websites and job fairs were held, giving an outline of the Agency and clarifying the kinds of human resources needed by the Agency to increase the number of applicants and reduce the number of those who are offered jobs but decline to accept them. Mid-career workers, including technical ones, were secured for assignment to the organizational units where they are required.

With consideration being given to appropriate personnel treatment, a wide variety of good researchers both at home and from abroad were employed as researches with a fixed term of office at each research center.

In order to assign an appropriate number of personnel to each organizational unit according to its work requirements and maximize manpower effectiveness, interviews about personnel assignment were conducted. Instructions were given to all the organizational units to identify work loads and job assignment

quantitatively, and they were questioned about the personnel situation, in order to assign an appropriate number of personnel, in particular support personnel, to each organizational unit.

3. Improvement of working environment

In order to offer a wider variety of training for learning laws and regulations and acquiring knowledge, an Audit and Compliance Office was formed on April 1, 2007, and a code of conduct and compliance and related regulations were formulated in December 2007, establishing an education and training system for compliance with laws and regulations. At the same time, problems requiring urgent, specific measures were coped with by drawing up plans for preventing improper acts on competitive and other funds or holding related explanatory sessions; or by other means.

In the improvement of the work environment, based on the responses to the questionnaire and the like sent out to all personnel between FY 2006 and 2007, efforts were made to offer a better support system with the emphasis on the prevention of sexual harassment, maintenance of normal mental health and child care assistance.

For the maintenance of safety in the workplace environment, basic safety policies were formulated and implemented, including establishing an organization and system for securing safety and appropriate emergency response; developing necessary documents in a systematic way; sharing information among personnel; and encouraging continued improvement activities. In addition, in order to enhance the safety management capability and emergency response capability of each member of the management staff, safety education plans were drawn up and implemented for new members of the management staff, laboratory practitioners, researchers performing on-board or ground duties, crisis management personnel and others.



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